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THE GREAT LAKES BOTANIST publishes papers on all aspects of the natural history of plants of North America north of Mexico, including systematics, floristics, ecology, conservation, botanical history, economic botany and ethnobotany, restoration, and other areas of organismal botany. Plant groups include vascular plants, bryophytes, fungi, and algae. The journal maintains the Great Lakes region as one area of special focus. The Great Lakes region is defined as the entirety of the states and provinces bordering any of the Great Lakes, that is, Michigan, Wisconsin, Minnesota, Illinois, Indiana, Ohio, Ontario, Pennsylvania, and New York.

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Vol. 59, Nos. 1–2 was mailed September 1, 2020.

IN THIS ISSUE

When this journal changed its name from *The Michigan Botanist* to *The Great Lakes Botanist* four years ago, it also announced that it would now publish articles on plants from throughout continental North America north of Mexico, rather than limiting its coverage to the Great Lakes region. In this issue, we publish the first article from outside the Great Lakes region, the first report of *Landoltia punctata* (Araceae) from the Ozarks. Although the major focus of the journal remains with the Great Lakes region, I would like to take this opportunity to invite the submission of more articles from the broader North American region.

This issue begins with a comprehensive vascular flora of Pierce Cedar Creek Institute, a biological field station in Barry County, Michigan. This article greatly increases the previously known flora of field station based on an enumeration made in the period 1999 to 2001, which reflects partly the increased size of the station, but more importantly "changes in vegetation associated with land management activities and natural and anthropogenic disturbances." In addition to the floristic enumeration itself, the article discusses the history of the field station, including changes in vegetation, describes the various vegetation communities, and provides information on the rare and listed species present at the station, as well as planted and otherwise non-native species present.

One way of assessing the effect of climate change on at-risk species and communities is to monitor the change over time in characteristics of rare plants, especially those that are disjunct from their main areas of distribution. This is a major focus of the second article, which assesses the response of 25 arctic and alpine species that occupy shoreline habitats on Isle Royale, an island in Lake Superior, to extreme changes in water level. Since these species are at or near the limits of the geographical ranges, they may be susceptible to additional stresses caused by low lake levels. In particular, the authors examined changes over 20 years in several individual, functional, and macrohabitat characteristics that may illuminate their ability to respond to warming trends and lake level changes.

Virginia Freire and co-authors provide an enumeration of the bryophytes (mosses and liverworts) at a 40-acre natural area in northeastern Wisconsin that has a particularly rich bryophyte flora. This is a follow-up to the earlier article by co-author Emmet Judziewicz enumerating the vascular plants of the same tract (*The Michigan Botanist* 43: 81–115. 2004), and serves as a companion piece to the article published last year listing the bryophytes of St. Martin Island, Michigan (*The Great Lakes Botanist* 58: 212–220). In both cases, the authors compare the bryophyte diversity of the area under study with that at several other Midwestern locales and discuss the ecological occurrence of particular species within the tract.

Fungal biodiversity is highly understudied, with respect both to the number of described species in relation to the estimated total, and to the geographical distribution of known species. DNA barcoding of specimens of macrofungi has proven to be a useful tool in increasing our knowledge in this area. The fourth ar-

ticle illustrates both the paucity of current knowledge and the efficacy of the use of DNA barcoding. Among fungal specimens collected in Dane County, Wisconsin, one of the more heavily studied areas in the state, DNA barcoding revealed three new records for the United States and an additional 14 records for the state of Wisconsin. In addition, additional genetic variants unknown in current databases were uncovered—future studies will indicate whether these are existing species or species new to science. In addition to increasing floristic knowledge, this study also discussed increased distributional knowledge, such as global distribution patterns of species previously thought to have much more limited distributions.

The fifth article examines an underexplored aspect of the effect of beaver activity on vegetation, in particular the indirect effect of cutting of saplings by beavers on the understory vegetation in non-riparian areas of the forest. The use of permanent plots established before the onset of beaver activity whose initial composition had been recorded made it possible to monitor and assess changes resulting from such activity.

In addition to the article on *Landoltia punctata*, this issue contains four additional Noteworthy Collections articles. A significant range extension of the state-endangered *Trillium erectum* is reported for Illinois. The invasive grass, *Microstegium vimineum* (Japanese stiltgrass), a native of eastern Asia that has proven to be a significant pest in much of the eastern United States, is here reported for the first time from Canada, specifically from the County of Niagara in southeastern Ontario. In two separate articles, Rob Routledge and his co-authors report two species from the Upper Peninsula of Michigan as new from the state—*Eriophorum russeolum* (Cyperaceae) (white-bristled russet cottongrass) and *Utricularia ochroleuca* (Lentibulariaceae) (yellowish-white bladderwort).

A book review of Daniel D. Palmer's *Michigan Ferns & Lycophytes* complements previous reviews of other recent books in these pages covering Michigan's flora, *Field Manual of Michigan Flora* (reviewed at *The Michigan Botanist* 52: 55–56), *Wetland Plants of Michigan* (reviewed at *The Michigan Botanist* 52: 112), and *Michigan Shrubs & Vines* (reviewed at *The Michigan Botanist* 54: 79–80).

——Michael Huft

VASCULAR FLORA OF PIERCE CEDAR CREEK INSTITUTE, BARRY COUNTY, MICHIGAN

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ABSTRACT

Pierce Cedar Creek Institute (PCCI) is a 335-ha (829-ac) nature center, environmental education center, and biological field station in Barry County, Michigan. A floristic inventory of approximately 125 ha (300 ac) of the property conducted from 1999 to 2001 resulted in the identification of 394 vascular plant species. Since that time, several important changes have taken place at PCCI, including additional land acquisitions and changes in vegetation associated with land management activities and natural and anthropogenic disturbances. These changes, in conjunction with the limited scope of the original floristic inventory and recent advances in plant taxonomy and systematics, were the impetus for an update and expansion of the original inventory. Following inspection of existing specimens and additional collecting in 2018–2019, a total of 767 vascular taxa (609 native taxa) are reported here from PCCI. Among these are eight species listed in Michigan as Endangered, Threatened, or Special Concern. Further inventories are recommended, including an inventory of deliberately introduced species at the main property and a complete inventory of the 23-ha (57-ac) "Little Grand Canyon" parcel east of the main property.

KEYWORDS: Pierce Cedar Creek Institute, Barry County, vascular plants, floristic inventory, flora.

INTRODUCTION

Pierce Cedar Creek Institute (PCCI) is a 335-ha (829-ac)[1] nature center, environmental education center, and biological field station located in south-central Barry County, Michigan (42.5369, –85.2967) (Figure 1). The Willard G. Pierce and Jessie M. Pierce Foundation purchased the original 225 ha (555 ac) in sections 19 and 30, Baltimore Township, in August 1998. Shortly following this initial acquisition, Slaughter and Skean (2003a, 2003b) conducted a floristic inventory of approximately 125 ha (300 ac) that resulted in the identification and collection of 394 vascular plant species (Slaughter and Skean 2003b). This paper presents a revised, expanded inventory of approximately 278 ha (688 ac)[1] following examination and annotation of previously collected specimens and additional field inventories in 2018 and 2019.

[1] The contiguous field station comprised ca. 278 ha (688 ac) at the time of this study in 2018. Acquisition of two additional parcels since that time increased the size of the main tract to 314 ha (772 ac). PCCI also owns a separate 23-ha (57-ac) parcel ("Little Grand Canyon") located approximately 1.5 km NE of the main field station. See Discussion.

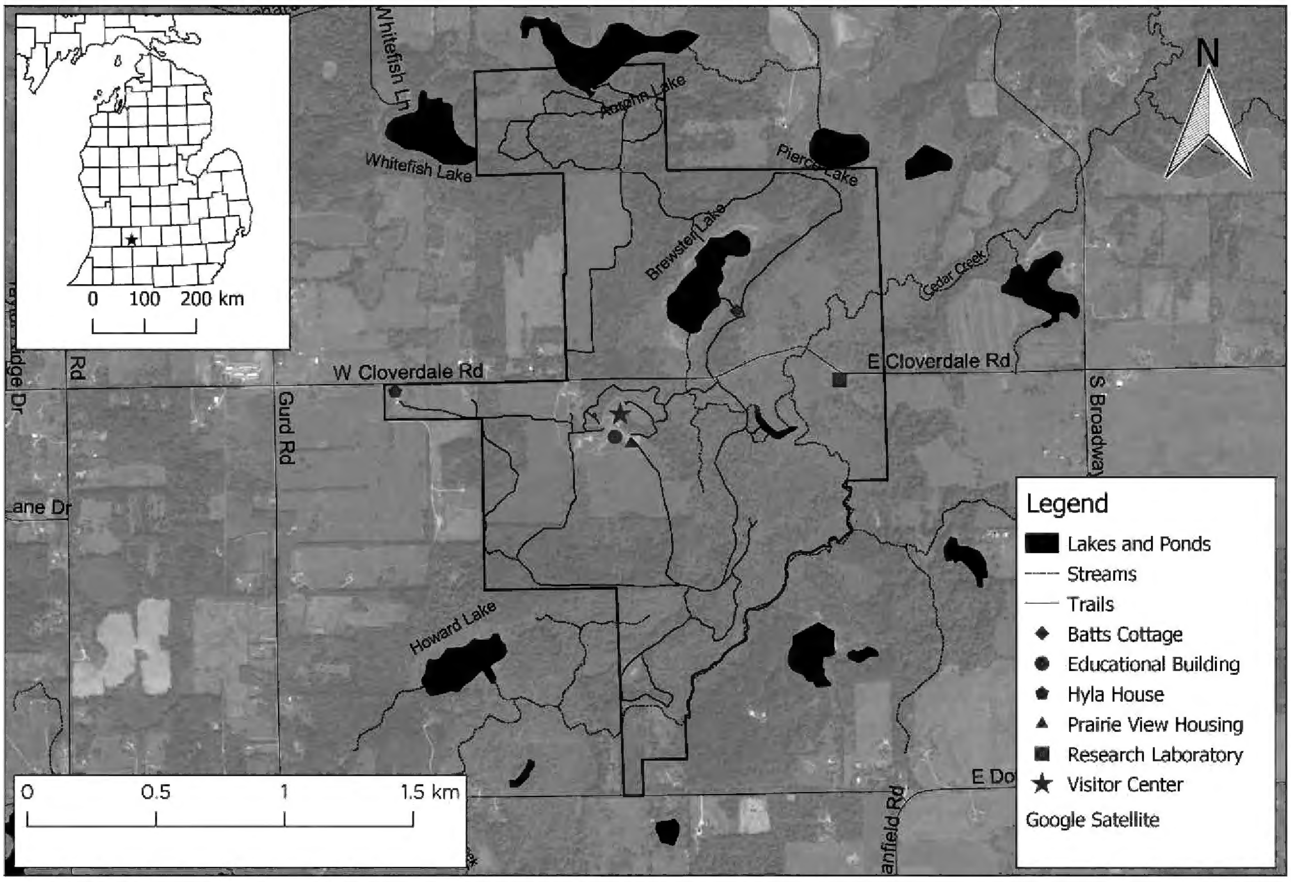

FIGURE 1. Location of Pierce Cedar Creek Institute in south-central Barry County, Michigan, USA. Dark outline delimits extent of property (278 ha, or 688 ac) circa 2018. Map created in QGIS Desktop 3.4.14-Madeira. Basemap: Google Satellite. Data: Pierce Cedar Creek Institute; State of Michigan–Michigan GIS Open Data.

Physical Description of the Study Area

Climate

Barry County has a warm-summer humid continental climate (Köppen–Geiger Classification Dfb), with cold winters, warm summers, and no dry season (Kottek et al. 2006). According to the Midwestern Regional Climate Center (MRCC), monthly average temperature (1981–2010 normals) at Hastings, the county seat, ranges from –5.1°C (22.8°F) in January to 21.2°C (70.2°F) in July, with an annual average of 8.4°C (47.2°F), growing season (May–October) average of 16.7°C (62.1°F), and an average freeze-free period of 150 days (MRCC 2019a, 2019b). Average annual liquid-equivalent precipitation (1981–2010 normals) is 95.1 cm (37.4 in), and average annual snowfall is 159.3 cm (62.7 in) (MRCC 2019c, 2019d). Regional climate is trending warmer and wetter. Average annual temperature has increased at a rate of 1.1°C/century (1.9°F/century) since 1895 and is expected to exceed 12°C (53°F) by 2069 (MRCC 2019e). Warming has been especially pronounced during the winter months of December–February. Average annual precipitation has increased at a rate of 11.7 cm/century (4.6 in/c.) since 1895 and is expected to exceed 100 cm (40 in) by 2069 (MRCC 2019e). Precipitation has increased primarily during the summer months of June–August.

FIGURE 2. View of the glacial tunnel valley, looking east from main campus. The tunnel valley is situated between two areas of higher-elevation till, visible in the foreground and at the horizon. Photo by B. S. Slaughter, May 2009.

Landforms

PCCI is situated in a high-relief, hummocky landscape shaped by stagnation of the retreating Saginaw Lobe of the Laurentide Ice Sheet (Kehew et al. 2012). A noteworthy aspect of the local physiography is the presence of several glacial tunnel valleys created by high-energy subglacial meltwater, apparent today as a series of northeast and southwest trending bands of lakes, wetlands, kames, eskers, and related landforms. One of these tunnel valleys (Figure 2) traverses PCCI, encompassing Brewster Lake, Cedar Creek, and adjacent wetlands and eskers (Ewald 2012; Kehew et al. 2012; Kehew et al. 2014). The northwestern portion of the property, including the main campus and Aurohn and Whitefish Lakes, is characterized by hummocky topography and surficial layers of more or less fine-textured diamicton, or till (Kehew et al. 2014). Smaller areas of sand and gravel outwash and ice-walled lakeplain are located south of Cedar Creek and near Hyla House and Meadow Lodge, respectively. Elevations range from approximately 258 m (846 ft) in the tunnel valley at Cedar Creek to 303 m (994 ft) on wooded hills east of Whitefish Lake (United States Geological Survey 2017).

Soils

Twenty-eight soil map units occur on the site (Figure 3) (USDA, NRCS 2018). Approximately 80 ha (200 ac), or 30% of the property consists of deep (>1 m), poorly drained organic soils of the Houghton series (Houghton muck). Houghton muck underlies the extensive wetlands in the glacial tunnel valley encompassing Cedar Creek and Brewster Lake, and smaller deposits are present

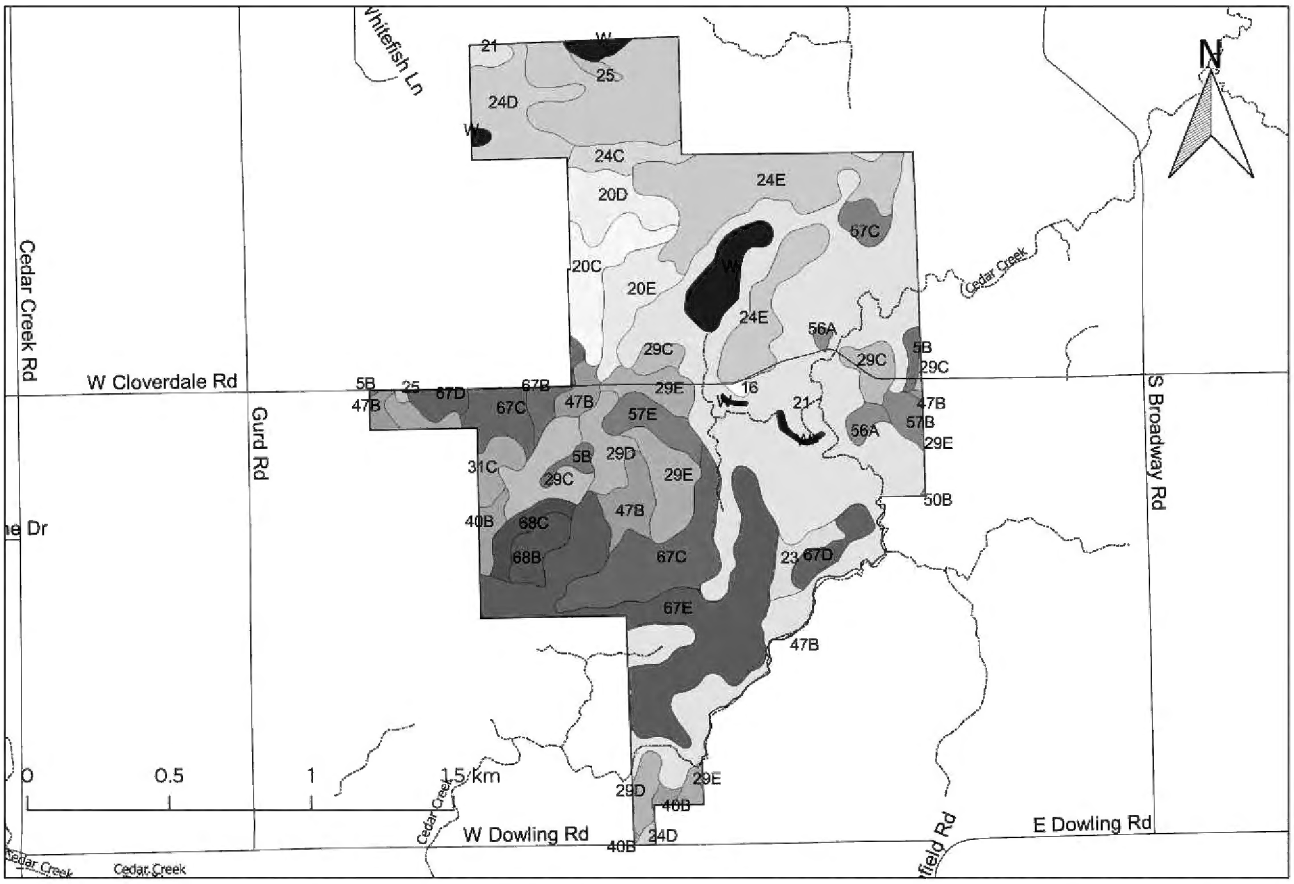

FIGURE 3. Twenty-eight (28) soil map units (MUs) are mapped for the PCCI main property, representing a diversity of textures (USDA, NRCS 2018). The broad lowlands of the glacial tunnel valley support extensive deposits of MU 21 (Houghton muck). Map created in QGIS Desktop 3.4.14-Madeira. Baselayer: Pierce Cedar Creek Institute; State of Michigan–Michigan GIS Open Data. Soil data: USGS, NRCS 2018.

near Whitefish and Pierce Lakes. Predominant upland soils are Filer loam (ca. 52 ha, or 130 ac) north of Cloverdale Road, and Marlette–Oshtemo complex (49 ha, or 120 ac) south of Cloverdale Road. These soil map units are primarily in forest cover at present, particularly on the steepest slopes. Old agricultural fields ("North Prairie") and some young forested acreage north of Cloverdale Road occur on Tekenink fine sandy loam; the old fields and prairie plantings south of Cloverdale Road occur on an array of mostly smaller, intergrading map units, including Perrinton loam, Marlette–Oshtemo complex, and coarser-textured deposits such as Coloma–Marlette complex and Coloma loamy sand. A rotosonic borehole drilled on the esker east of Brewster Lake reached sandstone bedrock (Marshall Formation) at approximately 197 m (646 ft) elevation (Ewald 2012). Sediment depth to bedrock at this location was 65.5 m (215 ft) and consisted primarily of alternating bands of bedded gravel and sand.

Historical Vegetation

Sediment cores from the Brewster Lake basin illustrate post-glacial succession typical for the region, with *Abies balsamea* (L.) Mill. (balsam fir) and *Picea* spp. (spruce) pollen predominating in the deepest (oldest) sediments, *Pinus* spp. (pines) in middle profiles, and hardwoods in the youngest sediments, coinciding with the establishment and eventual predominance of oak forests and beech–

maple forests over the past several thousand years (Honsowitz and Rohrer 2006; Hupy and Yansa 2009). At the time of the General Land Office (GLO) survey in 1826, oak–hickory forests covered much of the hummocky till west of the glacial tunnel valley, and beech–maple forest dominated similar landforms east of the tunnel valley (Comer et al. 1995). Lakes, ponds, and streams were typically bordered by mixed conifer swamps, shrub swamps, and emergent marshes. No significant areas of oak savanna or prairie were recorded by GLO surveyors in the immediate landscape (Comer et al. 1995).

Land Use and Current Vegetation

Human activity and land use were briefly discussed in Slaughter and Skean (2003a); more robust accounts are provided by Hovey (2008) and Howell and Lucas (2018). Slaughter and Skean (2003b) described and mapped six natural community types in an area approximating the location of the glacial tunnel valley, including Brewster Lake and Cedar Creek. Wetlands were classified as relict conifer swamp, southern wet meadow, and prairie fen based on the natural community classification used by Michigan Natural Features Inventory (MNFI) at that time (see Kost et al. 2007). Hardwood–conifer swamp and southern shrub-carr were described but not mapped. Wooded uplands were characterized as mesic southern forest south of Cloverdale Road and dry-mesic southern forest and dry southern forest north of Cloverdale Road. Jensen and Laureto (2014) developed a finer-grained classification for the upland forests based on vegetation, soil moisture, soil pH, nutrients, and topography. Other vegetation research at PCCI has primarily focused on grassland plantings.

Several important changes have taken place since the initial floristic inventory was conducted by Slaughter and Skean (2003a, 2003b). Two of these involve recent colonizations by the non-native insect *Agrilus planipennis* Fairmaire (emerald ash borer) and the native mammal *Castor canadensis* Kuhl (beaver). Emerald ash borer was first detected in Barry County in 2004, only two years after its initial detection in Wayne County (Emerald Ash Borer Information Network 2019). Over the past 15 years, a significant majority of the ashes at PCCI succumbed to *A. planipennis* infestations, although seedlings, young saplings, and resprouts are abundant in forest understories, and several mature trees treated with insecticides by PCCI staff persist and continue to set seed. The diffuse but attenuating impacts of *A. planipennis* sharply contrast with the localized but striking transfiguration of the Brewster Lake shoreline and nearby wetlands by dam-building beavers (see the *Wetlands* section in the Results below).

The other primary changes are associated with the development and growth of PCCI. The main property has grown from 225 ha (555 ac) in 1998 to 314 ha (772 ac)[2] at present. The most recent acquisition from the estate of Alice and

[2] The original 225 ha are protected under a conservation easement held by Southwest Michigan Land Conservancy (Howell and Lucas 2018). Management of remnant natural communities at PCCI is focused on maintenance of natural processes (and introduction of processes, e.g., prescribed fire, where appropriate), invasive species control, and deer population management. Timber removal is restricted to fallen trees that span hiking trails, and species introductions have been mostly restricted to prairie plantings and degraded habitats (Howell and Lucas 2018).

Kensinger Jones extended the northwestern boundary of the property to the eastern shore of Whitefish Lake and encompasses the entirety of Aurohn Lake. Prairie plantings, which covered ca. 4 ha (10 ac) in 1999, now cover 40 ha (98 ac). Prescribed burns have been implemented in these plantings and in natural habitats such as the large southern wet meadow/fen complex along Cloverdale Road (Howell and Lucas 2018). Other important stewardship activities have included the release of the leaf-beetle *Galerucella calmariensis* Duftschmidt for control of *Lythrum salicaria* (purple loosestrife); herbicide application, hand-pulling, cutting, and girdling to reduce populations of invasive plants; and the use of controlled hunting and exclosures to reduce the deleterious impacts of *Odocoileus virginianus* Zimmermann (white-tailed deer) on vegetative structure and composition (Howell and Lucas 2018). Limited introductions of native species to natural communities have also occurred. Activities unrelated to stewardship also impact the vegetation. For example, construction and maintenance of buildings and infrastructure and establishment of wildflower gardens and other plantings routinely disturb the soil and permit colonization by many weeds otherwise uncommon in or absent from the property.

METHODS

Vascular Plant Inventory

Collections were made on 19 dates from May to September 2018 and one day each in May and September 2019. Surveys covered all portions of the main property excluding a ca. 6 ha (14 ac) parcel south of Cedar Creek, north of Dowling Road. Collections consisted primarily of species not previously vouchered from the field station and species requiring further identification. Ornamentals and other planted species that were not represented by native or naturalized individuals were not collected and are excluded from the PCCI flora. Specimens were deposited at PCCI. Duplicates for the University of Michigan Herbarium (MICH) were collected for most rare species and species not previously vouchered from Barry County.

Redetermination of Existing Specimens

Mounted and labeled specimens collected by Slaughter and Skean (2003b) or succeeding researchers at PCCI were examined and annotated, where necessary, in the fall of 2018. In addition to correcting misidentifications, annotation labels were created for specimens affected by recent nomenclatural changes, as published in Voss and Reznicek (2012) and updated in MICHIGAN FLORA ONLINE (2011). Several specimens cited by Slaughter and Skean (2003b) and deposited at Albion College (ALBC) were examined and annotated, where necessary, by J. D. Skean, Jr. in the winter of 2019. Specimens collected in 2018 were loaned to MICH and annotated by A. A. Reznicek in 2019.

RESULTS

A total of 626 specimens of native or naturalized taxa were collected in 2018 and 2019, including 499 unicates (single collections) and 127 duplicates (the collection locations are shown in Figure 4). A total of 437 taxa were vouchered, including 434 species and infraspecific taxa and three named hybrids. An annotated checklist is presented in Appendix 1. Among these were 382 taxa not previously collected or reported by Slaughter and Skean (2003b). Examination of existing specimens resulted in several annotations; these are reflected in the an-

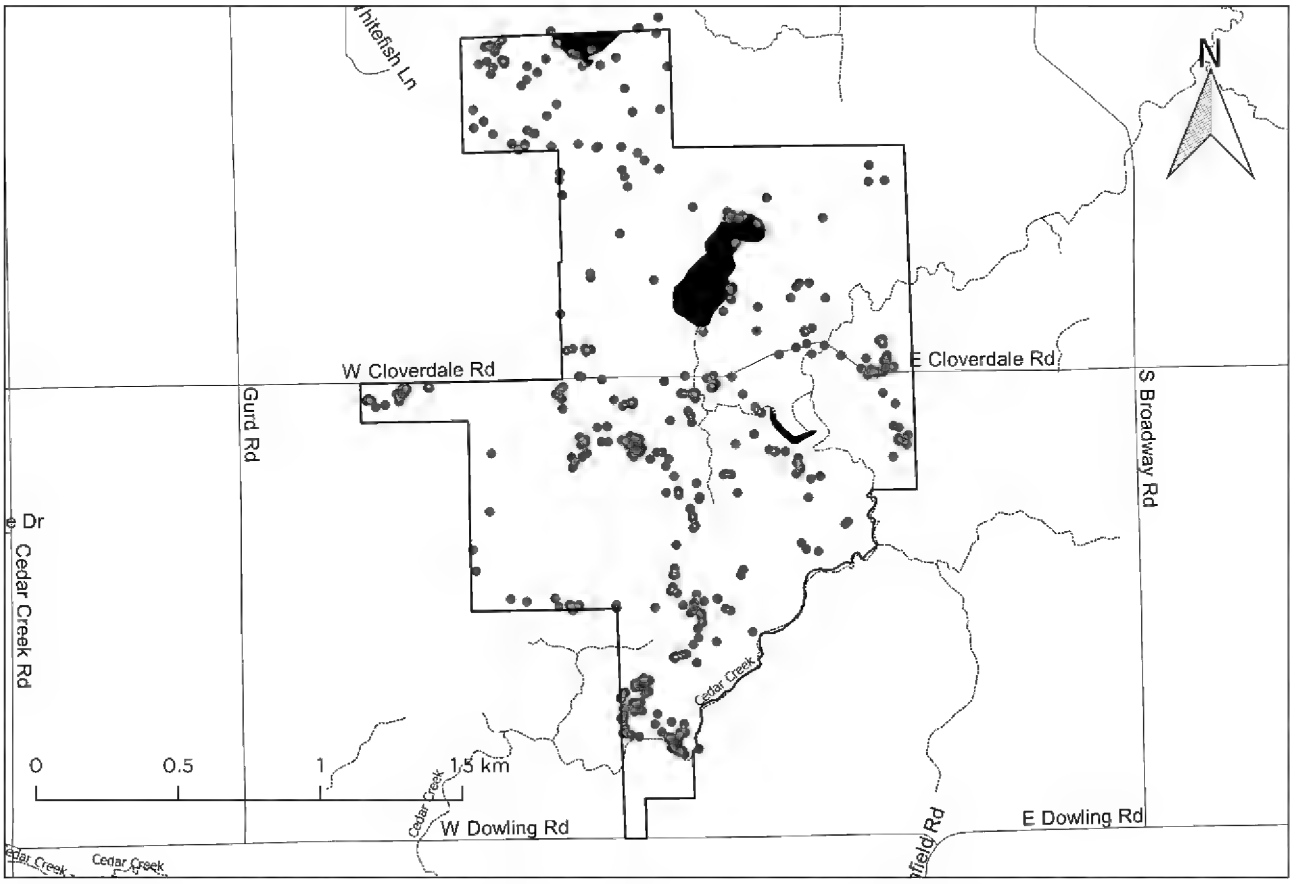

FIGURE 4. Locations of collections, 2018–2019, indicated by closed circles. Map created in QGIS Desktop 2.18.7. Baselayer: Pierce Cedar Creek Institute; State of Michigan–Michigan GIS Open Data.

notated checklist (Appendix 1), as compared to the annotated checklist published in Slaughter and Skean (2003b). Seventy-eight mounted specimens collected by other researchers and stored at PCCI were also examined and annotated where necessary, resulting in the addition of one species, *Bromus pubescens* (Canada brome), to the checklist. Collections lacking basic collection notes or comprised of inadequate samples were not examined further. Queries of specimen databases at the University of Michigan (MICHIGAN FLORA ONLINE 2011) and Consortium of Midwest Herbaria (2018) yielded 15 additional specimens. Although these were not examined and verified, they represent easily identified species that are vouchered by other, verified collections from PCCI, and they are therefore referenced in the annotated checklist (Appendix 1).

Rare Species

Eight species listed as Endangered (SE), Threatened (ST), or Special Concern (SC) in Michigan were documented and vouchered in 2018. These are the first state-listed plants vouchered from the main property; two others have been collected from the Institute's 23-ha (57-ac) "Little Grand Canyon" parcel in the eastern half of Section 20, Baltimore Township, and several others have been reported from that location but are not substantiated with specimens.

Carex amphibola (SC) (Figure 5) is an uncommon (or perhaps only overlooked due to its similarity to the widespread *C. grisea*) woodland sedge known

FIGURE 5. *Carex amphibola* (sect. *Griseae*) is an uncommon species of rich upland forests, distinguished from the common *C. grisea* by its clearly trigonous perigynia (MICHIGAN FLORA ONLINE 2011). Photo by B. S. Slaughter, June 2018.

from 11 counties in southern Lower Michigan (MICHIGAN FLORA ONLINE 2011). At PCCI, *C. amphibola* was observed locally in the mesic beech–maple forest and on wooded banks above Cedar Creek in Section 30. It occurred in small colonies and is likely present elsewhere in mature forests on the property. *Carex amphibola* is also known from the "Little Grand Canyon" parcel, where it was collected in 2012 (*B. S. Slaughter 737*, MICH).

Carex seorsa (ST) occurs at scattered locations in Lower Michigan, primarily in the southwestern counties, where it favors swamps and depressions in upland forests (MICHIGAN FLORA ONLINE 2011). Two populations were observed at PCCI, both on quaking organic deposits in small, isolated kettle depressions within upland forests, one east of Whitefish Lake in Section 19, and the other near the Cedar Creek Trail in Section 30. *Carex seorsa* was previously known from one other location (Yankee Springs Recreation Area) in Barry County (*A. A. Reznicek 11564*, MICH).

Helianthus hirsutus (hairy sunflower) (SC) is known from scattered locations in Michigan, where it inhabits fields, thickets, and forest borders (MICHIGAN FLORA ONLINE 2011). This species may be overlooked due to its similarity to the widespread, common *Helianthus divaricatus* L. (woodland sunflower). At PCCI, two colonies of *Helianthus hirsutus* were noted in Section 19, both occurring at wooded borders. This is the first report of this species from Barry County.

FIGURE 6. *Poa paludigena* (bog bluegrass) is frequent in swamp forests at PCCI. This state-threatened species is considered vulnerable across its range in the Eastern and Midwestern United States (NatureServe 2018). Photo by B. S. Slaughter, June 2018.

Poa paludigena (bog bluegrass) (ST) (Figure 6) is a small, inconspicuous grass of swamp forests, usually occurring in the vicinity of groundwater seepages and springs (MICHIGAN FLORA ONLINE 2011). The species was observed in several areas within northern white-cedar–tamarack–hardwood swamps in Section 30, often along or near spring runs. Although *Poa paludigena* appears to be the most prevalent of the eight state-listed plant species at PCCI, it is considered globally vulnerable, or at moderate risk of extinction or elimination, across its range (NatureServe 2018). It is known from two other locations in Barry County (*A. A. Reznicek 11566*, MICH; *B. S. Slaughter 595*, MICH).

Potamogeton pulcher (spotted pondweed) (SE) is an aquatic plant known from fewer than 10 locations in Michigan, where it occurs primarily in boggy lakes (MICHIGAN FLORA ONLINE 2011). At PCCI, *Potamogeton pulcher* occurs in shallow water around the shrub swamp in the southeastern arm of Whitefish Lake and in the moat around the wooded bog in its northeastern arm. This is the second report of the species from Barry County (*L. A. Wilsmann s.n.*, MICH, MSC).

Symphyotrichum drummondii (Drummond's aster) (ST) is a showy aster of open forests, woodlands, savanna remnants, and old fields ranging mostly to the west of Michigan (MICHIGAN FLORA ONLINE 2011). *Symphyotrichum drummondii* is poorly collected from Michigan, reflecting actual rarity and/or

morphological ambiguity[3]. At PCCI, *S. drummondii* is frequent in dry old fields, particularly in Section 19.

Wolffia brasiliensis (pointed water meal) (ST) is a tiny floating aquatic species related to *Lemna* spp. (duckweeds). This diminutive plant was not known from Michigan until it was discovered in Berrien County in 1986 (*K. Dritz s.n.*, MICH, MOR). It has since been collected from several additional stations in west-central and southwestern Lower Peninsula and has recently been proposed for delisting by the Michigan Rare Plant Technical Advisory Committee. At PCCI, *Wolffia brasiliensis* is abundant in the moat surrounding the forested bog in the northeastern arm of Whitefish Lake but was not observed elsewhere.

Zizania aquatica (southern wild-rice) (ST) occurs in several small patches along Cedar Creek, where it was discovered and documented by Alex Wieten (Gun Lake Tribe) and Corey Lucas (PCCI) in August 2018. A sample was subsequently collected from a colony just south of Cloverdale Road. In Michigan, *Zizania aquatica* is distributed primarily in the southern Lower Peninsula, where it occurs in shallow, sluggishly flowing water over loose sediments with little immediate competition. The PCCI population is the first recorded for Barry County.

Other Noteworthy Species

Sphenopholis nitida (shining wedgegrass) was collected from a wooded bank northeast of Whitefish Lake. This species is known from 13 counties in southern Michigan, but most records are old; only two specimens have been collected after 1941 (MICHIGAN FLORA ONLINE 2011). The apparent decline of *S. nitida* follows a pattern documented for several other species closely associated with open oak forests and woodlands, including the state-listed *Agrimonia rostellata* Wallr. (beaked agrimony) (ST), *Eupatorium sessilifolium* L. (upland boneset) (ST), *Geum virginianum* L. (pale avens) (SC), *Hieracium paniculatum* L. (panicled hawkweed) (ST), *Linum virginianum* L. (slender yellow flax) (ST), *Silene stellata* (L.) W. T. Aiton (starry campion) (ST), and *Solidago bicolor* L. (white goldenrod) (SE). For this reason, *Sphenopholis nitida* was recommended to be added to Michigan's list of Special Concern species in 2019.

In addition to rare species, PCCI supports several taxa at or near their southern range limits in southern Michigan. *Circaea alpina* (small enchanter's-nightshade), *Coptis trifolia* (goldthread), *Gaultheria hispidula* (creeping-snowberry), and *Mitella nuda* (naked miterwort) were discussed briefly in Slaughter and Skean (2003a). Several others were newly collected in 2018, including several sedges (i.e., *Carex arctata*, *C. brunnescens*, and *C. deweyana*), *Equisetum sylvaticum* (woodland horsetail), *Hydrocotyle americana* (water-pennywort), and *Malaxis monophyllos* subsp. *brachypoda* (white adder's-mouth). Most of these are represented by few modern collections from southern Michigan (MICHIGAN FLORA ONLINE 2011), and many former stations are no longer suitable

[3] Most Michigan specimens are annotated as "near *S. drummondii*" or "with some influence of" the widespread, common *S. urophyllum*.

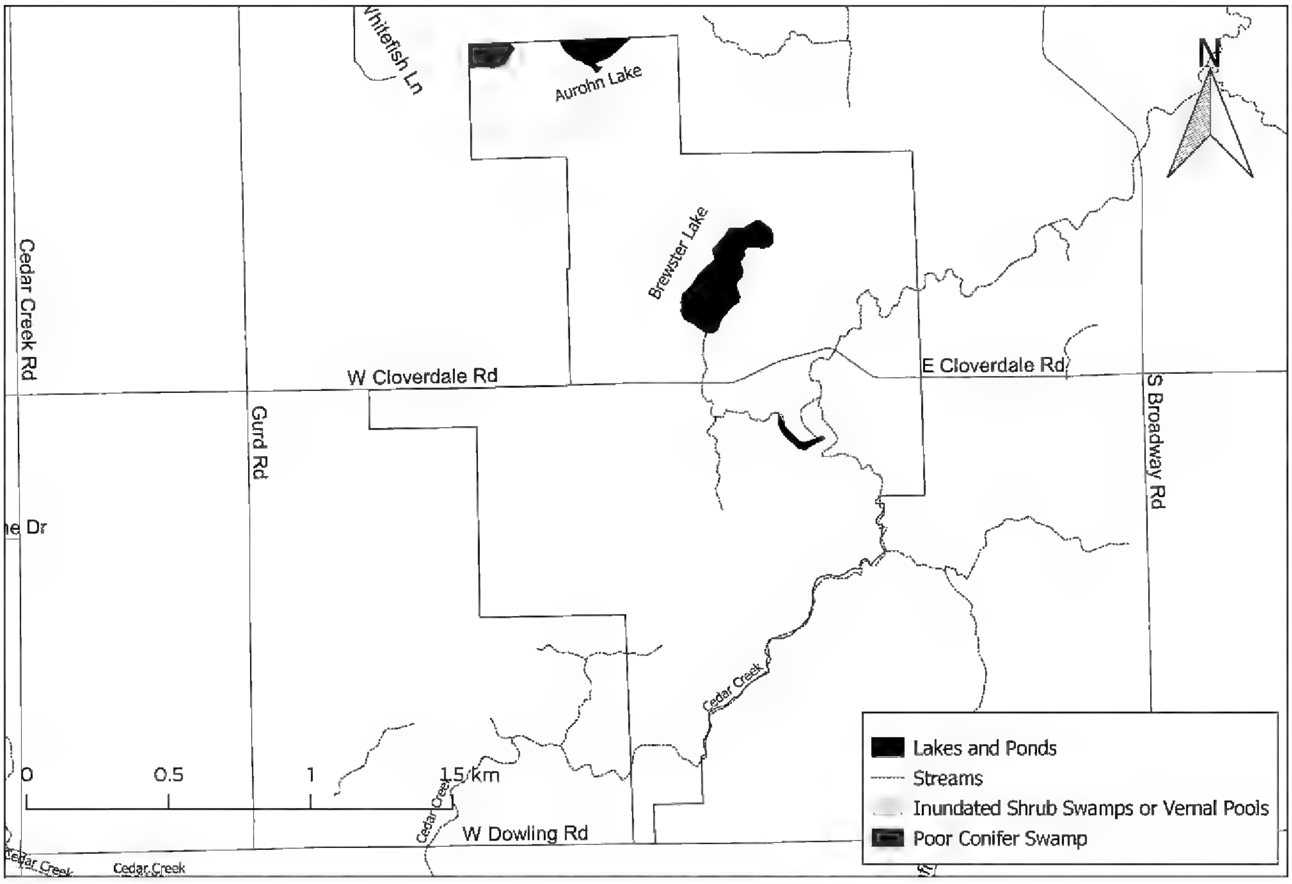

FIGURE 7. Locations of aquatic habitats (lakes and streams) and kettle wetlands (inundated shrub swamp, poor conifer swamp, and vernal pool). Map created in QGIS Desktop 3.4.14-Madeira. Baselayer: Pierce Cedar Creek Institute; State of Michigan–Michigan GIS Open Data. Landcover Data: Pierce Cedar Creek Institute.

for a variety of reasons (see *Wetlands* in Vegetation and Natural Communities section below).

Vegetation and Natural Communities

Aquatic Habitats

Aquatic habitats (Figure 7) cover approximately 7 ha (18 ac)[4]. Among these are Brewster Lake (5 ha, or 13 ac), a stretch of Cedar Creek on the original parcels, small portions of Whitefish Lake, and the entirety of the man-made Aurohn Lake on the Jones parcels. Typical species occurring in shallow portions of these bodies of water include *Ceratophyllum demersum* (coontail), *Lemna* spp. (duckweeds), *Nuphar advena* and *N. variegata* (yellow pond-lilies), *Nymphaea odorata* (sweet-scented waterlily), *Potamogeton* spp. (pondweeds), *Schoenoplectus acutus* (hardstem bulrush), *Spirodela polyrhiza* (greater duckweed), *Stuckenia pectinata* (sago pondweed), and *Wolffia* spp. (water meals). Several species of the non-vascular green algae, *Chara* spp. (muskgrasses), are also common. Bands of *Decodon verticillatus* (whorled loosestrife) line the shores of the natural lakes and Cedar Creek.

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[4] Acreage figures are based GIS shapefiles provided by PCCI, as interpreted and amended following field surveys. Parcels acquired after completion of the field surveys were not classified or mapped.

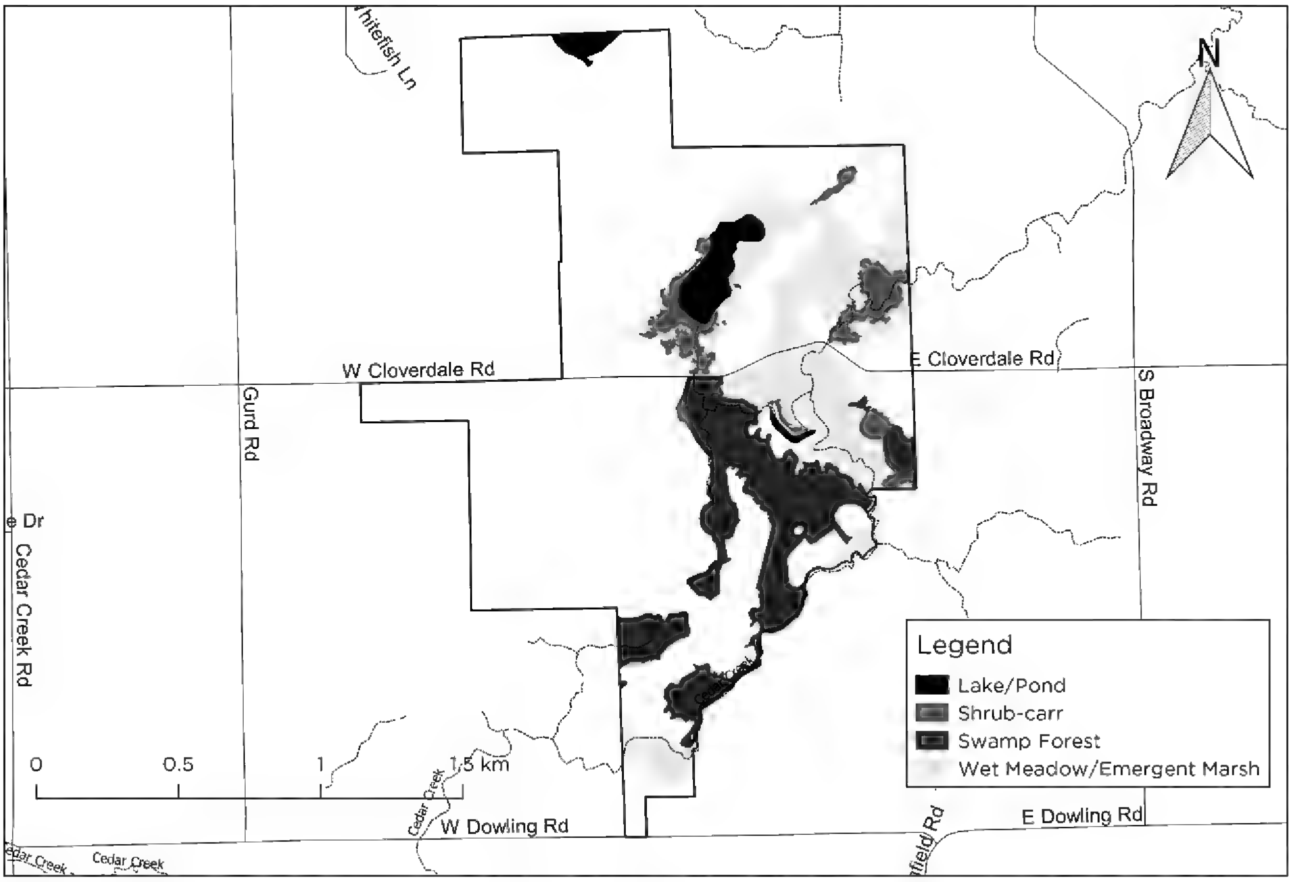

FIGURE 8. Southern wet meadow (including limited areas of fen), southern shrub-carr, and swamp forest communities cover ca. 94 ha (232 ac) of the main property. Map created in QGIS Desktop 2.18.7. Baselayer: Pierce Cedar Creek Institute; State of Michigan–Michigan GIS Open Data. Landcover Data: Pierce Cedar Creek Institute.

Wetlands

Wetlands (Figure 8) cover approximately 97 ha (240 ac), or 35% of the property. Swamp forests dominated by *Thuja occidentalis* (northern white-cedar), *Larix laricina* (tamarack), and mixed hardwoods occupy approximately 41 ha (102 ac). The stands dominated by northern white-cedar (Figure 9) are especially notable, as they comprise the largest, highest-quality rich conifer swamp in southwestern Lower Michigan (Kost 2002; Cohen et al. 2014; MNFI 2018). Few similar substantial stands of northern white-cedar persist in southern Michigan, and several of these have degraded considerably due to the deleterious effects of high deer densities, hydrological disturbances, pollution (such as road salt runoff), and the invasion and spread of the emerald ash borer and subsequent loss of canopy ashes (*Fraxinus* spp.) (MNFI 2018). Stands dominated by *Larix laricina* (tamarack) are also mapped by MNFI as an element occurrence of rich tamarack swamp (Kost 2001a; Cohen et al. 2014; MNFI 2018), although portions of the tamarack swamp are degraded by invasive species and die-off caused by beaver impoundments (Figure 10). For further discussion of these natural communities, see Slaughter and Skean (2003a). The remainder of the swamp forest acreage consists of mixed hardwoods, including *Acer rubrum* (red maple), *Betula alleghaniensis* (yellow birch), *Carpinus caroliniana* (hornbeam), *Fraxinus nigra* (black ash), and *Ulmus americana* (American elm), often associated with small

FIGURE 9. Rich conifer swamp dominated by *Thuja occidentalis* (northern white-cedar) and *Symplocarpus foetidus* (skunk-cabbage) occurs between the esker and Cedar Creek south of Cloverdale Road. Seeps and small drainages punctuate the distinctly sloped peat deposits. Photo by B. S. Slaughter, May 2009.

groves or scattered individuals of northern white-cedar and tamarack. These stands of southern hardwood swamp and hardwood–conifer swamp occur primarily in semi-enclosed basins that experience fluctuating hydrology (Slaughter et al. 2007; Slaughter 2009; Cohen et al. 2014). One such depression north of Cloverdale Road opposite the Research Lab experiences seasonal ponding and desiccation and supports a community dominated by *Acer saccharinum* (silver maple), *Fraxinus pennsylvanica* (green ash), and an understory of *Cephalanthus occidentalis* (buttonbush).

Open, sedge-dominated wetlands characterize approximately 43 ha (107 ac) of the field station (Figure 8). Although these are described as prairie fen by PCCI, most of the acreage consists of southern wet meadow that grades into emergent marsh near Cedar Creek (Figure 11) (Kost 2001b; Slaughter and Skean 2003a; Cohen et al. 2014; Howell and Lucas 2018). The southern wet meadow is dominated by coarse-leaved herbaceous species such as *Carex stricta*, *C. lacustris*, *Eutrochium maculatum* (joe-pye-weed), *Phragmites australis* subsp. *americanus* (reed), and *Symphyotrichum firmum* (smooth swamp aster). Dominance by coarse vegetation is likely the result of seasonal (and interannual) lowering of the water that permits the aerobic decomposition and mineralization of limiting nutrients such as nitrogen and phosphorus (Rydin and Jeglum 2013). Coarse vegetation may have also benefited from historical land use, including

FIGURE 10. A *Castor canadensis* (beaver) dam impounded this small drainage, resulting in significant areas of tree-kill. Note the rafts of decaying vegetation (esp. lower left) deposited by receding water following removal of the dam. Photo by B. S. Slaughter, May 2009.

road construction; pasturing of cows, sheep, and pigs; soil fertilization; and mowing of marsh hay (Hovey 2008). These disturbances may account for the restricted occurrence of species more typical of prairie fen such as *Comandra umbellata* (bastard-toadflax), *Hypoxis hirsuta* (star-grass), and *Zizia aurea* (golden alexanders).

The small fen on the shoreline of Brewster Lake that was noted by Slaughter and Skean (2003b) was shortly thereafter inundated by beaver impoundment, with concomitant changes in species composition and structure (Figures 12 and 13). Fen species persist there where inundation was absent or of shorter duration and severity. Perhaps the most striking fen-like communities occur on the lower slopes of the swamp forests south of Cloverdale Road, where consistent groundwater seepage maintains a high water table that supports luxuriant patches of *Sphagnum* spp. (sphagnum mosses) and peatland species such as *Drosera rotundifolia* (round-leaved sundew), *Eriophorum gracile* (slender cotton-grass), *Sarracenia purpurea* (pitcher-plant), and several orchids, situated among open groves of northern white-cedar, tamarack, *Toxicodendron vernix* (poison-sumac), and *Vaccinium corymbosum* (highbush blueberry) (Figure 14).

Southern shrub-carr comprises approximately 10 ha (25 ac) of the property, typically in patches on shores and in ecotones between forests (upland and low-

FIGURE 11. A vista of southern wet meadow and emergent marsh occurs between lobes of swamp forest near Cedar Creek. Photo by B. S. Slaughter, May 2009.

FIGURE 12. The initial beaver dam did not appreciably alter the shore fen along Brewster Lake. Photo by B. S. Slaughter, May 2009.

FIGURE 13. Continued beaver activity eventually raised water levels in Brewster Lake which inundated the shore fen (foreground) and killed trees (upper left). Photo by B. S. Slaughter, May 2018.

FIGURE 14. The orchids *Calopogon tuberosus* (grass-pink) (lower right) and *Cypripedium reginae* (showy lady-slipper) (center) grow among *Sphagnum* and several other peatland species in a springy, open *Larix–Thuja* swamp reminiscent of northern Michigan. Photo by B. S. Slaughter, June 2018.

FIGURE 15. Patches of southern shrub-carr (middle) occupy ecotones between sedge meadows (foreground) and swamp forest (background). Photo by B. S. Slaughter, May 2009.

land) and wet meadow or emergent marsh (Cohen et al. 2014) (Figures 8, 15). Typical shrubs at PCCI include *Cornus* spp. (dogwoods), *Ribes americanum* (wild black currant), *Salix* spp. (willows), and *Toxicodendron vernix* (poison-sumac). Shrub-carr has expanded since the time of the author's initial studies in 1999–2001. Dogwoods have overtaken portions of the sedge meadow near the Beech Maple Ridge Trailhead in the absence of disturbance (which, historically, likely consisted of mowing/haying and grazing, and now consists of prescribed fire). Invasive shrubs, particularly *Elaeagnus umbellata* (autumn-olive), *Lonicera* spp. (honeysuckles), and *Rosa multiflora* (multiflora rose), are a nuisance in shrub-carr and open swamps.

Several small, isolated kettle depressions support seasonally dry vernal pools or muck substrates supporting buttonbush-dominated inundated shrub swamps (Cohen et al. 2014) (Figure 7). Most of these kettles occur on the Jones parcel in the vicinity of Aurohn and Whitefish Lakes. Although these features cover only 1 ha (3 ac) in total, several plants are apparently restricted to them, most notably the state-threatened sedge *Carex seorsa*. The northeastern arm of Whitefish Lake consists of a ca. 4-ha (9-ac) wooded bog, or poor conifer swamp, a portion of which occurs on the Jones parcel of PCCI. Although at a distance it appears very similar to the rich tamarack swamps on the property, this community differs in its development on a floating peat mat within the lake basin and the presence of a patchy acidic sphagnum peat layer at its surface (Cohen 2006; Cohen et al.

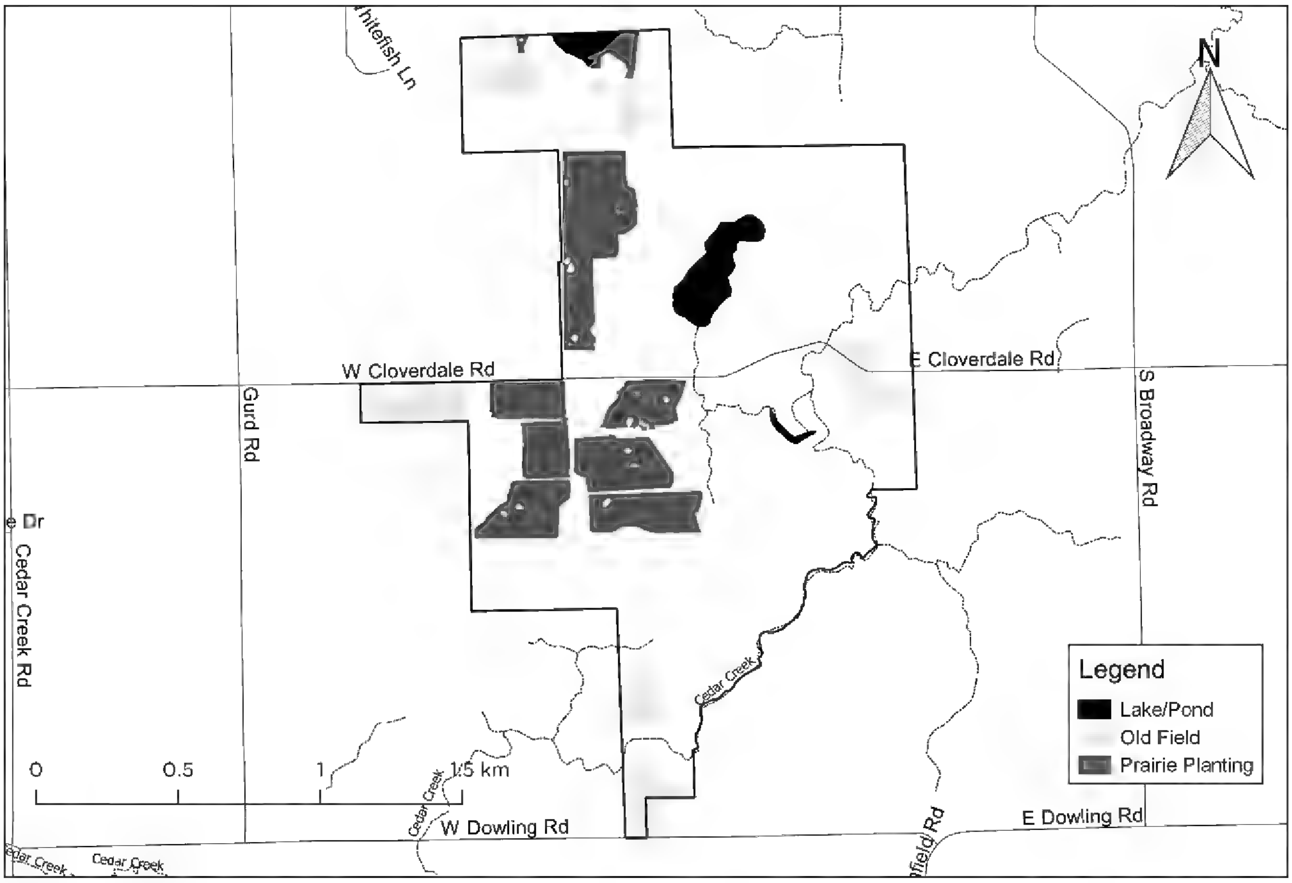

FIGURE 16. Locations of old fields and prairie plantings, totaling ca. 58 ha (143 ac). Structures and trees located within old fields and prairie plantings are unshaded. Map created in QGIS Desktop 2.18.7. Baselayer: Pierce Cedar Creek Institute; State of Michigan–Michigan GIS Open Data. Landcover Data: Pierce Cedar Creek Institute.

2014). Many species that occur here, such as *Carex trisperma*, *Chamaedaphne calyculata* (leatherleaf), *Cypripedium acaule* (pink lady-slipper), and *Ilex mucronata* (mountain holly), have not been documented elsewhere on the property. The surrounding moat supports populations of the state-listed *Potamogeton pulcher* (SE) and *Wolffia brasiliensis* (ST).

Uplands

Upland habitats have been impacted to a greater degree than other communities at PCCI by agriculture, timber harvest, and other disturbances (Slaughter and Skean 2003b; Hovey 2008; Howell and Lucas 2018). Approximately 144 of the 188 ha (356 of the 465 ac) were tilled and supported crops into the mid- to late 20th century. Approximately 58 ha (143 ac) continue to support open habitats, including 18 ha (44 ac) of old fields and 40 ha (98 ac) converted to prairie plantings (Figure 16). Old fields are generally dominated by non-native herbaceous species including *Bromus inermis* (smooth brome), *Centaurea stoebe* (spotted knapweed), *Dactylis glomerata* (orchard grass), *Daucus carota* (Queen-Anne's-lace), *Hieracium caespitosum* (king devil), *Phleum pratense* (timothy), *Poa pratensis* (Kentucky bluegrass), *Rumex acetosella* (sheep sorrel), and *Solanum carolinense* (horse-nettle). Characteristic native species include *Desmodium glabellum* (tick-trefoil), *Erigeron strigosus* (daisy fleabane), *Solidago altissima* (tall goldenrod), *Symphyotrichum drummondii*, and *S. pilosum*

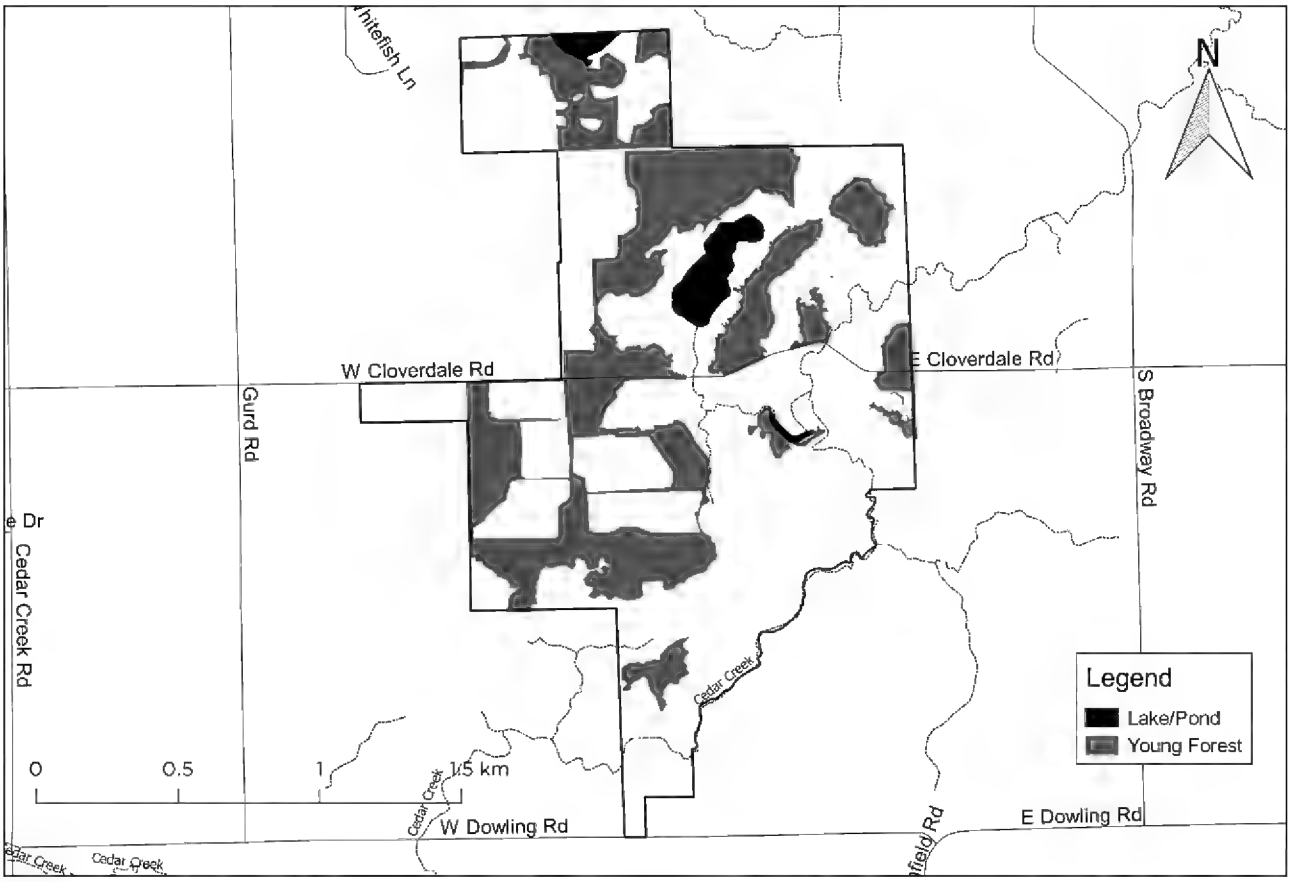

FIGURE 17. Young forests cover moderate slopes where agriculture was abandoned in the latter half of the 20th century. Map created in QGIS Desktop 2.18.7. Baselayer: Pierce Cedar Creek Institute; State of Michigan–Michigan GIS Open Data. Landcover Data: Pierce Cedar Creek Institute.

(frost aster). A small, sandy clearing near the southern margin of the property supports several species typical of oak barrens and dry sand prairie, such as *Andropogon virginicus* (broom-sedge), *Cyperus lupulinus* (slender sand sedge), several *Dichanthelium* spp. (panic grasses), *Hieracium gronovii* (hairy hawkweed), *H. longipilum* (prairie hawkweed), *Krigia virginica* (dwarf dandelion), and *Nuttallanthus canadensis* (blue toadflax). Native and non-native woody species are locally prevalent in these areas. A list of species introduced to the prairie plantings is provided in Appendix 2.

Young forests occupy the largest area of any vegetation cover type on the property, collectively exceeding 80 ha (200 ac). Many of these occur on former agricultural lands that were taken out of production beginning in the 1950s (Hovey 2008), and they typically occupy an intermediate landscape position between relatively level areas, which were taken out of production more recently, and hilly areas that were historically grazed but never tilled (Figure 17). A variety of trees are present, especially *Acer rubrum*, *Fraxinus americana* (white ash), *Juglans nigra* (black walnut), *Prunus serotina* (black cherry), and *Quercus rubra* (red oak). Planted conifers such as *Pinus nigra* (Austrian pine) occur in small stands. Understories support a ubiquitous association of mostly weedy woody and herbaceous species, especially *Carex gracillima* (sedge), *Circaea canadensis* (enchanter's-nightshade), *Elaeagnus umbellata*, *Galium aparine* (cleavers), *Geum canadense* (white avens), *Lonicera* spp., *Parthenocissus quin-*

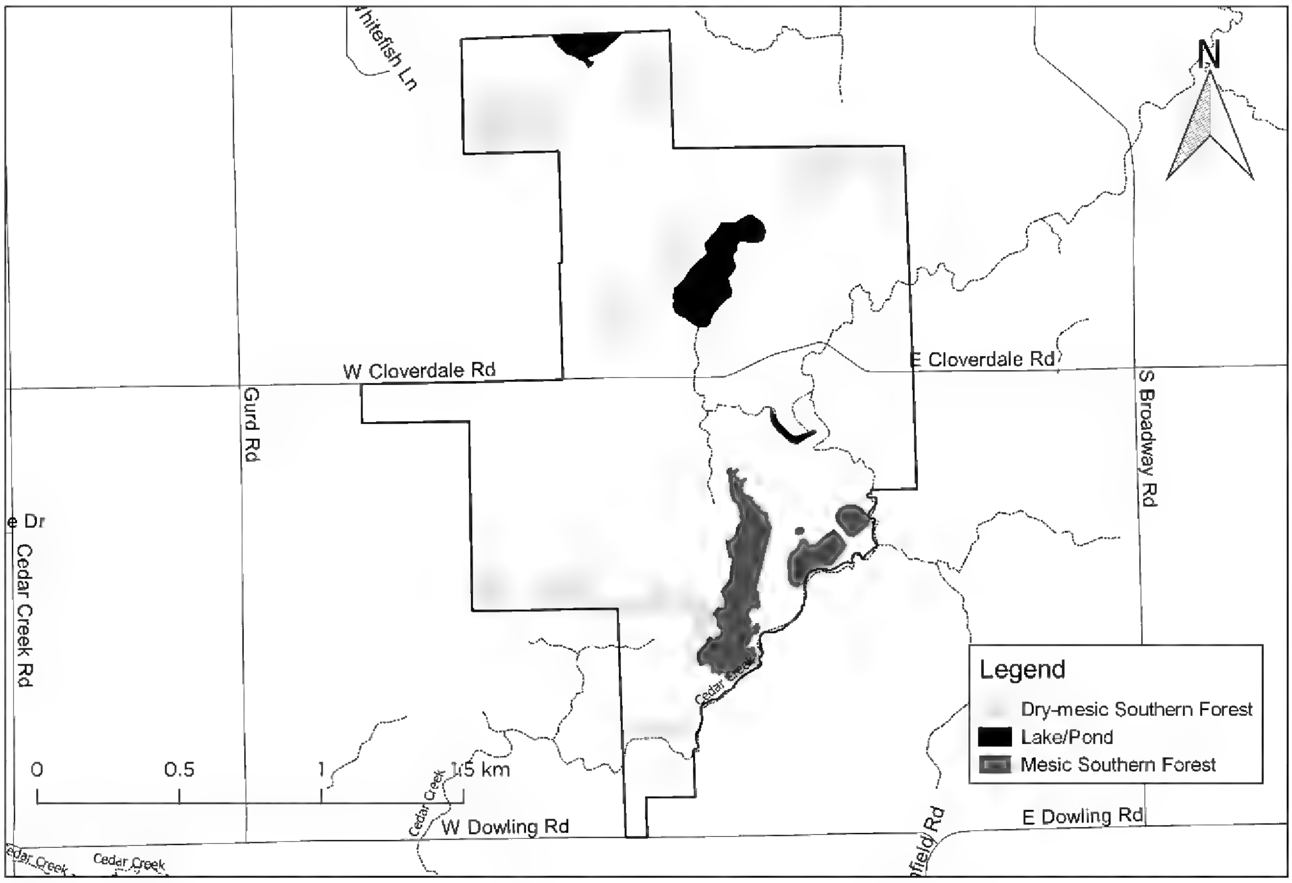

FIGURE 18. Mature, second-growth dry-mesic and mesic southern forests occur primarily on the steepest slopes, including eskers and copses within the glacial tunnel valley and hummocky till at its margins. Map created in QGIS Desktop 2.18.7. Baselayer: Pierce Cedar Creek Institute; State of Michigan–Michigan GIS Open Data. Landcover Data: Pierce Cedar Creek Institute.

quefolia (Virginia creeper), *Persicaria virginiana* (jumpseed), *Ribes cynosbati* (prickly gooseberry), *Rosa multiflora*, *Rubus* spp. (blackberries), *Sanicula odorata* (black snakeroot), *Toxicodendron radicans* (poison-ivy), and *Vitis riparia* (riverbank grape).

Mesic southern forest and dry-mesic southern forest (Figure 18) are the predominant upland natural communities (Slaughter and Skean 2003a; Kost et al. 2007). Mesic southern forest dominated by *Fagus grandifolia* (beech) and *Acer saccharum* (sugar maple) covers approximately 12 ha (30 ac) on the esker and several copses south of Cloverdale Road, surrounded by swamp forest (Figure 19). Dry-mesic southern forest, dominated primarily by *Quercus rubra* (red oak), occurs in several small patches and covers approximately 37 ha (92 ac) in total. Both habitats are discussed in Slaughter and Skean (2003b); important changes over the past 15–20 years include the death of most canopy and subcanopy *Fraxinus* spp. (ashes) and a significant recovery of the herbaceous layer in some stands as a result of targeted deer hunts and mortality associated with epizootic hemorrhagic disease. Most notably, drifts of flowering *Trillium grandiflorum* (common trillium) occur in areas that were essentially denuded by deer browse in the late 1990s. The dry southern forest indicated by Slaughter and Skean (2003b) on the eskers north of Cloverdale Road is comprised of young stands not representative of that natural community type, although vegetation typical of dry southern forests occurs locally on coarse soils and southerly exposures, as on the wooded bank above Whitefish Lake.

FIGURE 19. Mature *Acer saccharum* (sugar maple) and *Fagus grandifolia* (beech) cloak the esker and tower over the adjacent swamp forest south of Cloverdale Road. Photo by B. S. Slaughter, May 2009.

DISCUSSION

A total of 1,582 specimens are referenced in the annotated checklist of vascular plants, representing 1,067 unique collections (551 unicates, 515 duplicates, and one photographic voucher) (Appendix 1). These collections represent 767 vascular plant taxa, comprising 765 species (including infraspecific taxa) and two unmapped hybrids (MICHIGAN FLORA ONLINE 2011) (Table 1). The vouchered, spontaneous[5] flora at PCCI represents just over one-quarter (26%) of the statewide flora, including 605 (33%) of the 1808 species native to Michigan (MICHIGAN FLORA ONLINE 2011)[6]. Approximately 70% of the total taxa and 68% of the native taxa vouchered from Barry County occur at PCCI (MICHIGAN FLORA ONLINE 2011).

A total of 103 plant families are represented, comprised of two families of lycophytes, seven families of ferns, two families of conifers, and 92 families of angiosperms (Table 1). The families Poaceae (92 taxa), Asteraceae (80 taxa), and Cyperaceae (76 taxa) account for nearly one-third of the PCCI flora. Statewide,

[5] See Appendix 2 and Howell and Lucas (2018) for lists of species deliberately introduced or planted but not documented from native or naturalized populations at PCCI.

[6] A few of the taxa native to Michigan occur at PCCI only as escapes from plantings.

TABLE 1. Numbers of families, genera, and species (native and introduced) of vascular plants collected from Pierce Cedar Creek Institute (PCCI), 1969–2019, in each of the major taxonomic groups. Native species are native to Michigan, though not necessarily to PCCI.

			Species		
Taxonomic Group	Families	Genera	Native	Introduced	Total
Lycophytes	2	2	5	0	5
Ferns	7	13	22	0	22
Conifers	2	5	6	3	9
Angiosperms	92	345	576	155	731
Total	103	365	609	158	767
Percentage of Total Species			79.4%	20.6%	

these three families account for 29% of the flora (MICHIGAN FLORA ONLINE 2011). The genus *Carex* is particularly well-represented, and 61 (41%) of the 150 species native to southern Michigan occur at PCCI. Conversely, Ericaceae and Fabaceae, families consisting primarily of species adapted to nutrient-poor soils, are underrepresented due to the natural scarcity of such habitats at PCCI and possibly the mesophication of historically suitable habitats through agricultural practices, fire suppression, and other human-mediated factors. Several species from both families (e.g., *Lathyrus ochroleucus*, *Pyrola elliptica*, and *Vaccinium pallidum*) are now highly localized and/or restricted to edaphic microhabitats.

Vascular plant richness at PCCI is comparable to that reported from other important botanical sites in southern Lower Michigan. In fact, the number of vouchered taxa from PCCI slightly exceeds figures from Kalamazoo Nature Center (Bassett 2011) and Warren Dunes State Park (Smith and Woodland 2006), both larger sites with longer histories of botanical exploration. The high species richness at PCCI can be attributed to a variety of factors, including the presence of a diversity of landforms (Ewald 2012; Kehew et al. 2012; Kehew et al. 2014); slopes and aspects (United States Geological Survey 2017); soil types (USDA, NRCS 2018); natural communities (Slaughter and Skean 2003a, 2003b; Cohen et al. 2014; Howell and Lucas 2018); and vegetative associations (Jensen and Laureto 2014). Disturbances associated with historical (Hovey 2008) and recent (Howell and Lucas 2018) land management also contribute to the creation of conditions suitable for a variety of plant species, especially weedy annuals.

CONCLUSIONS

The annotated checklist of vascular plants for PCCI is now taxonomically congruent with MICHIGAN FLORA ONLINE (2011) and representative of most of the main property (see footnote 2). The results of this project should prove beneficial to research on the ecology and floristics of the field station and land management and stewardship activities. PCCI is especially well-suited as a field laboratory for plant identification courses due to its diverse habitats and naturally occurring flora, the variety of additional species deliberately intro-

duced to prairie plantings, and its relatively compact size and accessibility. The updated flora should also be a valuable reference for surveys of other taxonomic groups, such as host- and habitat-specific insects. Based on the results of this study and previous work, several recommendations for additional work follow.

Additional Inventory

Based on the number of taxa vouchered to date, the sustained relatively high frequency of new species encountered during the main 2018 study period, and observations of several species not yet vouchered, the true vascular flora of PCCI likely exceeds 800 taxa. Additional inventory and collecting is recommended, with emphases on early season surveys for spring ephemerals and early-flowering trees and shrubs; *Crataegus* spp. (hawthorns), many of which were stunted and did not flower in 2018 due to repeated deer browse; aquatic plants; surveys of parcels acquired since the time of this study; and the collection of species previously observed by PCCI staff or observed but not collected during this study, such as *Lobelia cardinalis* L. (cardinal-flower).

Planted Species

Examples of all excluded species (plantings) should be collected and deposited at the PCCI Herbarium for reference. Recording and archiving “metadata” associated with these species provides critical information for ecological interpretation, research, and stewardship. The collection of voucher specimens of species introduced to the site that are listed as Endangered, Threatened, or Special Concern in Michigan should be emphasized to avoid misinterpretation by researchers, regulatory agencies, and the public. A partial list of excluded species vouchered from PCCI or reported to have been introduced to PCCI (excluding species introduced only to landscaping near buildings; Howell and Lucas 2018) is provided in Appendix 2.

Other Parcels

The 23-ha (57-ac) “Little Grand Canyon” parcel located east of the main field station (Section 20, Baltimore Township) should be thoroughly inventoried to complete the floristic assessment of PCCI lands. Several partial checklists of the flora have been recorded, and a few specimens, including some representing species not found on the main property, have been vouchered and deposited at MICH. An efficient approach could involve documenting all species present and making collections of species not vouchered elsewhere from PCCI. The same approach should be followed for additions to the main property, including the two parcels added following the completion of the 2018–2019 field surveys.

Vegetation Monitoring

Permanent transects and/or macroplots should be established and sampled to evaluate trends in vegetative structure and species composition, particularly in

areas where stewardship activities such as invasive species control and application of prescribed fire are planned or are in progress. O'Connor (2007) provided guidance for the development of monitoring strategies and examples of species and habitat monitoring protocols implemented in Michigan. Carefully placed and designed permanent sampling units can also provide critical data on the impacts of unplanned, stochastic disturbances, such as the destruction of ash trees by emerald ash borer and the fragmentation and disintegration of shoreline fen due to beaver activity, both of which occurred subsequent to the initial floristic inventory completed by Slaughter and Skean (2003a). As O'Connor (2007) noted, monitoring provides critical feedback that enables land managers to adapt strategies as necessary to benefit conservation targets and negate unintended damage.

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APPENDIX 1. Annotated checklist of the vascular plants of Pierce Cedar Creek Institute, Barry County, Michigan.

The following is a checklist of vascular plant species collected at Pierce Cedar Creek Institute from 1969 to 2019. Most of the specimens comprising the annotated checklist were collected from 1999 to 2001 (Slaughter and Skean 2003b) and in 2018. Existing collections curated at Pierce Cedar Creek Institute, including those reported by Slaughter and Skean (2003b) and several more recent specimens collected by other researchers, were examined and annotated, where necessary, by the author in 2018. In addition, several specimens of unmistakable species housed at other herbaria that were not examined by the author or verified for inclusion in *Field Manual of Michigan Flora* (Voss and Reznicek 2012) or MICHIGAN FLORA ONLINE (2011) are cited in this checklist.

Scientific and common names follow MICHIGAN FLORA ONLINE (2011). Taxa are arranged by major clade (and major subclades for ferns and angiosperms) then alphabetically by family. Family assignments for the most part follow MICHIGAN FLORA ONLINE (2011), with exceptions reflecting recent updates by the Angiosperm Phylogeny Group (APG IV 2016) (APG). In these in-

stances, family assignments used in MICHIGAN FLORA ONLINE (2011) are included in the checklist and cross-referenced to the APG familial placements.

Introduced species are indicated with an asterisk (*) preceding the scientific name. Species without an asterisk are considered native to Michigan (MICHIGAN FLORA ONLINE 2011) but are not necessarily native to PCCI (see annotations). Many species have been introduced to PCCI, particularly in the vicinity of Batts Cottage and other structures and more recently in several grassland plantings. Species that occur at PCCI only as plantings are not included in the checklist unless they are documented as part of the spontaneous flora (MICHIGAN FLORA ONLINE 2011) and/or have the potential to escape. See Appendix 2 for a list of excluded taxa.

Collections are indicated by collector initials, collection number, and location of specimens, following Index Herbariorum (Thiers 2018). Collectors are as follows: BSS (Bradford S. Slaughter); BSW (Beverly S. Walters); EA (Emily Arendsen); GJP (Gary J. Pierce); JDS (J. Dan Skean, Jr.); JS (Jacob Swets); JF (Jennifer Fuller); JLL (James Luyten); JL (Jianhua Li); MB (Madison Buckner); MV (Michael VanDyken); MW (Micaela Wells); RWP (Richard W. Pippen); WTG (William T. Gillis). Herbaria are as follows: ALBC (Albion College); BALT (Towson University); HCHM (Hope College); MICH (University of Michigan); PCCI (unofficial designation for Pierce Cedar Creek Institute); WMU (Western Michigan University).

Species distribution and abundance indications are as follows. A: abundant (widespread, in many habitats, perhaps as a dominant). LA: locally abundant (localized but in very high numbers). C: common (widespread, in few to many habitats with high frequency, or as a dominant in one major habitat). LC: locally common (localized in high numbers). F: frequent (widespread, in few to many habitats with low frequency, or common in one habitat). O: occasional (widespread in low numbers or occurring in two or more small colonies). R: rare (widespread in very low numbers or localized in relatively low numbers).

Locations and habitats are briefly noted for each species following the abundance ranks. For native and naturalized species that are also present as plantings, a dagger (†) and list of associated locations as reported in Howell and Lucas (2018) follows the main entry. A few collections of planted individuals of these species are housed at PCCI and are indicated in square brackets following the list of planted areas. Locations of plantings are as follows: BL (Brewster Lake); C (Central Prairie); FB (Fire Breaks); HP (Hedgerow Prairie); LT (Lupine Trail Prairie); ME (Middle East Prairie); MON (Monarch Waystations); MW (Middle West Prairie); N (North Prairie); NE (North East Prairie); NW (North West Prairie); SE1 (Southeast Prairie 1); SE2 (Southeast Prairie 2); SP (Sand Prairie); SW (South West Prairie); WOOD (North Prairie Young Forest); YF (Tall Grass Prairie Trail Young Forest).

Species listed as Endangered, Threatened, or Special Concern in Michigan (following MNFI 2009) are denoted as such following the annotations on locations and habitats.

LYCOPHYTES (Clubmosses, Spikemosses, and Quillworts)

LYCOPODIACEAE

Dendrolycopodium hickeyi (W. H. Wagner, Beitel & R. C. Moran) A. Haines, Pennsylvania clubmoss—*BSS 2509* (PCCI). R, wooded bog, Whitefish Lake.

Dendrolycopodium obscurum (L.) A. Haines, ground-pine—*BSS 2565* (PCCI). R, shaded margins of sandy old field near terminus of Cedar Creek Trail.

Diphasiastrum digitatum (A. Braun) Holub, ground-cedar—*BSS 2091* (PCCI). LC, shaded margins of sandy old field near terminus of Cedar Creek Trail.

EQUISETOPHYTE FERNS (Horsetails and Scouring-rushes)

EQUISETACEAE

Equisetum arvense L., common horsetail—*BSS 63*, *99*, *105* (ALBC, PCCI). F, scattered in a variety of habitats, occurring more often than other *Equisetums* in disturbed areas.

Equisetum ×ferrissii Clute, Ferriss' scouring rush—*BSS 2307* (MICH, PCCI). LC, margins of sandy old field near terminus of Cedar Creek Trail.

Equisetum fluviatile L., water horsetail—*BSS 329* (ALBC), *2171* (MICH), *2174* (PCCI). F, open swamps, springy areas, shores.

Equisetum hyemale L., scouring rush—*BSS 2092* (PCCI). O, wooded banks, old fields, roadsides.

Equisetum palustre L., marsh horsetail—*BSS 89* (ALBC, PCCI), *333* (ALBC). R, springy areas in open swamps.

Equisetum sylvaticum L., woodland horsetail—*BSS 2088* (MICH, PCCI). R, wooded toeslope near Cedar Creek.

OPHIOGLOSSOPHYTE FERNS (Whisk ferns and Adder's-tongues)

OPHIOGLOSSACEAE

Botrypus virginianus (L.) Michx., rattlesnake fern—*BSS 331*, *338*, *342* (ALBC). O, cedar-tamarack swamps.

Sceptridium dissectum (Spreng.) Lyon, cut-leaved grape-fern—*BSS 318* (ALBC, PCCI). O, young forests and thickets on sandy soil.

LEPTOSPORANGIATE FERNS

ASPLENIACEAE

Asplenium platyneuron (L.) D. C. Eaton, ebony spleenwort—*JDS 4085* (ALBC, PCCI). O, clearings, thickets, young weedy forests.

Athyrium filix-femina (L.) Roth var. *angustum* (Willd.) G. Lawson, lady fern—*BSS 406*, *474* (ALBC). C, upland forests, moist thickets, and wetland borders.

Deparia acrostichoides (Michx.) Desv., silvery spleenwort—*BSS 2197* (PCCI). F, rich upland forests and wetland borders.

Onoclea sensibilis L., sensitive fern—*BSS 57* (ALBC, PCCI). C, wetlands and depressions in upland forests.

Thelypteris noveboracensis (L.) Nieuwl., New York fern—*BSS 2183* (PCCI). F, low hardwoods and swamp borders.

Thelypteris palustris Schott, marsh fern—*BSS 65*, *265* (ALBC, PCCI). C, all but the most shaded wetlands.

ATHYRIACEAE – see ASPLENIACEAE

BLECHNACEAE

Woodwardia virginica (L.) Smith, Virginia chain-fern—*BSS 2372* (PCCI). LC, margin of bog, Whitefish Lake.

DENNSTAEDTIACEAE

Pteridium aquilinum (L.) Kuhn var. *latiusculum* (Desvaux) A. Heller, bracken fern—*JDS 4084* (ALBC, PCCI). O, ± sandy forests and borders.

DRYOPTERIDACEAE

Dryopteris carthusiana (Vill.) H. P. Fuchs, spinulose woodfern—*BSS 2194* (MICH); *BSS 2195*, *2216* (PCCI). F, upland forests and swamp borders.

Dryopteris cristata (L.) A. Gray, crested shield fern—*BSS 299* (ALBC, PCCI), *475* (ALBC). F, swamp forests.

Dryopteris intermedia (Willd.) A. Gray, evergreen woodfern—*BSS 343*, *426* (ALBC). F, upland forests, swamps.

Polystichum acrostichoides (Michx.) Schott., Christmas fern—*BSS 293* (ALBC, PCCI). F, mature beech-maple and oak forests, especially on slopes and low copses.

ONOCLEACEAE – see ASPLENIACEAE

OSMUNDACEAE

Osmunda claytoniana L., interrupted fern—*BSS 160* (ALBC, PCCI). O, upland forests and moist thickets.

Osmunda regalis L., royal fern—*BSS 298* (ALBC, PCCI). O, swamps and buttonbush depressions.

Osmundastrum cinnamomeum (L.) C. Presl, cinnamon fern—*BSS 81* (ALBC, PCCI), *340* (ALBC). C, swamps and wet thickets.

PTERIDACEAE

Adiantum pedatum L., maidenhair fern—*BSS 278* (ALBC, PCCI). F, mature upland forests and swamps.

THELYPTERIDACEAE – see ASPLENIACEAE

CONIFERS

CUPRESSACEAE

Juniperus communis L., common juniper—*BSS 313* (ALBC, PCCI). R, noted originally from disturbed ground (Slaughter and Skean 2003a).

Juniperus virginiana L., red-cedar—*JDS 4040* (ALBC, PCCI). C, young forests, borders, thickets, old fields, and wetlands.

Thuja occidentalis L., white-cedar—*JDS 4080* (ALBC, PCCI), *WTG 13863* (HCHM). C, Brewster Lake shoreline and dominant in swamps near Cedar Creek. See Slaughter and Skean (2003a).

PINACEAE

Larix laricina (Du Roi) K. Koch, tamarack—*BSS 104* (ALBC, PCCI). C, swamps, shrub-carr, wet meadows. Locally dominant. See Slaughter and Skean (2003b).

**Picea pungens* Engelm., blue spruce—*JDS 4240* (ALBC). Originally collected from a planted tree; R as an escape in sandy old field near terminus of Cedar Creek Trail.

**Pinus nigra* J. F. Arnold, Austrian pine—*BSS 2526* (PCCI). LC, small planting with a few young recruits just N of "North Prairie," S of Aurohn Lake.

Pinus resinosa Aiton, red pine—*JDS 4046* (ALBC, PCCI). Originally collected from a planted tree; R as an escape in sandy old field near terminus of Cedar Creek Trail.

Pinus strobus L., white pine—*JDS 4235* (ALBC). Originally collected from a planted tree; as a naturally occurring species, O, seedlings and saplings, presumably all established from plantings, although some occurring in natural settings (e.g., margin of cedar swamp).

**Pinus sylvestris* L., Scots pine—*JDS 4045* (ALBC, PCCI). Originally collected from a planted tree; R as an escape in sandy old field near terminus of Cedar Creek Trail.

ANGIOSPERMS (Flowering Plants)

BASAL ANGIOSPERMS

CABOMBACEAE

Brasenia schreberi J. F. Gmel., water-shield—*BSS 2365* (PCCI). LC, Whitefish Lake.

NYMPHAEACEAE

Nuphar advena (Aiton) W. T. Aiton, yellow pond-lily—*BSS 120* (ALBC, PCCI), *2347* (PCCI). F, lakes and Cedar Creek.

Nuphar variegata Durand, yellow pond-lily—*BSS 2344* (PCCI). LC, Brewster Lake, where more common than *Nuphar advena*.

Nymphaea odorata Aiton, sweet-scented waterlily—*BSS 2345* (PCCI). F, lakes and Cedar Creek.

MAGNOLIIDS

ARISTOLOCHIACEAE

Asarum canadense L., wild-ginger—*BSS 24* (ALBC, PCCI). O, moist wooded copses, swamp borders. †WOOD.

LAURACEAE

Lindera benzoin (L.) Blume, spicebush—*BSS 286* (ALBC, PCCI). C, swamps, wet thickets, moist hardwood forests.

Sassafras albidum (Nutt.) Nees, sassafras—*BSS 306* (ALBC, PCCI), *431* (ALBC). O, upland forests and thickets; invading sandy old fields.

MAGNOLIACEAE

Liriodendron tulipifera L., tulip tree—*BSS 297* (ALBC, PCCI). F, upland forests, swamps, openings.

MONOCOTS

ACORACEAE

**Acorus calamus* L., sweet-flag—*BSS 88* (ALBC, PCCI). LC, springy open wetlands.

ALISMATACEAE

Alisma triviale Pursh, northern water-plantain—*BSS 2409* (PCCI). O, exposed marsh and pond bottoms and vernal pools.

Sagittaria latifolia Willd., common arrowhead—*BSS 186*, *266*; *JDS 4075* (ALBC, PCCI). F, open springs, shores.

AMARYLLIDACEAE

Allium burdickii (Hanes) A. G. Jones, wild leek—*BSS 2027* (MICH, PCCI). O, rich upland forests, especially on lower slopes.

Allium canadense L., wild garlic—*JDS 4233* (ALBC). Along moist trails. Abundance unknown; not observed in 2018. †WOOD.

**Narcissus pseudonarcissus* L., daffodil—*JDS 4030* (ALBC, PCCI). R, near old foundation S of Cloverdale Road.

ARACEAE

Arisaema triphyllum (L.) Schott, jack-in-the-pulpit—*BSS 28*, *33* (ALBC, PCCI). C, widespread in wet to dry shaded habitats. †WOOD.

Calla palustris L., wild calla—*BSS 2220* (PCCI). O, buttonbush depressions and Whitefish Lake bog.

Lemna minor L., common duckweed—*BSS 79* (ALBC, PCCI), *2275* (MICH, PCCI). F, same habitats as *Lemna turionifera* but apparently more restricted, occurring consistently in spring runs.

Lemna trisulca L., star duckweed—*BSS 2517* (PCCI). LC, Aurohn Lake.

Lemna turionifera Landolt, red duckweed—*BSS 2067* (MICH, PCCI). C, lakes, Cedar Creek, and associated drainages and springs.

Peltandra virginica (L.) Schott & Endl., arrow-arum—*BSS 2248* (PCCI). F, shores and drainages.

Spirodela polyrhiza (L.) Schleid., greater duckweed—*BSS 2056* (PCCI). LC, Aurohn Lake, Brewster Lake, and outlets.

Symplocarpus foetidus (L.) Nutt., skunk-cabbage—*BSS 86* (ALBC, PCCI). A, swamp forests, wet thickets, wet meadows, seeps, and low areas in upland forests.

Wolffia borealis (Engelm.) Landolt & Wildi ex Gandhi, Wiersema & Brouillet, dotted water meal—*BSS 2058* (PCCI), *2069* (MICH). LC, Aurohn Lake and ponded stream south of Brewster Lake; much less frequent than co-occurring *Wolffia columbiana*.

Wolffia brasiliensis Wedd., pointed water meal—*BSS 2374* (MICH, PCCI). LA, bog lagg, Whitefish Lake. **THREATENED.**

Wolffia columbiana H. Karst., common water meal—*BSS 2057* (PCCI), *2068* (MICH). LA, Aurohn Lake and ponded stream south of Brewster Lake, often in dense masses at the surface.

ASPARAGACEAE

**Asparagus officinalis* L., garden asparagus—*BSS 2223* (PCCI). O, old fields and roadsides.

**Convallaria majalis* L., lily-of-the-valley—*BSS 2205* (MICH, PCCI). LC, along Cloverdale Road near Research Lab, where spreading to fields and wetland margins.

Maianthemum canadense Desf., Canada mayflower—*BSS 100* (ALBC, PCCI). C, swamps (especially closed-canopy) and upland forests.

Maianthemum racemosum (L.) Link, false spikenard—*BSS 2119* (PCCI). F, rich upland forests. †WOOD.

Maianthemum stellatum (L.) Link, starry false Solomon-seal—*BSS 109* (ALBC, PCCI). O, sedge meadows and wet thickets.

Polygonatum biflorum (Walter) Elliott, Solomon-seal—*BSS 2141* (PCCI). R, rich upland forests. †WOOD.

Polygonatum pubescens (Willd.) Pursh, downy Solomon seal—*BSS 85* (ALBC, PCCI). F, mature upland forests and swamps.

Uvularia grandiflora Sm., bellwort—*BSS 2142* (PCCI). R, rich upland forests and tamarack swamps. †WOOD.

ASPHODELACEAE

**Hemerocallis fulva* (L.) L., orange day-lily—*BSS 175* (ALBC, PCCI). LC, Cloverdale Road.

CONVALLARIACEAE – see ASPARAGACEAE

CYPERACEAE

Carex alata Torr., winged sedge—*BSS 153* (ALBC, PCCI), *2337* (PCCI). O, wet meadows and shores, mostly near Brewster Lake.

Carex albursina E. Sheld., sedge—*BSS 2031* (PCCI). O, rich upland forests.

Carex amphibola Steud., sedge—*BSS 2126* (PCCI). O, rich oak and beech-maple forests on well-drained soils. **SPECIAL CONCERN.**

Carex aquatilis Wahlenb. var. *substricta* Kük., sedge—*BSS 2169* (PCCI). LC, shores.

Carex arctata Boott, sedge—*BSS 2033* (MICH, PCCI). O, mature upland forests.

Carex atlantica L. H. Bailey subsp. *capillacea* (L. H. Bailey) Reznicek, sedge—*BSS 2371* (PCCI). R, wooded bog, Whitefish Lake.

Carex aurea Nutt., sedge—*BSS 2276a* (MICH, PCCI). R, springy open cedar-tamarack swamp.

Carex bebbii (L. H. Bailey) Fernald, sedge—*BSS 435* (ALBC). O, open wetlands and swamp borders.

Carex blanda Dewey, sedge—*BSS 12*, *13* (ALBC, PCCI). C, forests, thickets, clearings, and borders of old fields; disturbed areas. †WOOD.

Carex bromoides Willd., sedge—*BSS 328* (MICH), *2063* (PCCI). C, swamps and wet thickets; moist areas in upland forests.

Carex brunnescens (Pers.) Poir. subsp. *sphaerostachya* (Tuck.) Kalela, sedge—*BSS 2201* (PCCI). O, margins of buttonbush depressions; wooded bog, Whitefish Lake.

Carex cephaloidea (Dewey) Dewey, sedge—*BSS 2133* (MICH, PCCI). O, forests and thickets.

Carex cephalophora Willd., sedge—*BSS 2120*, *2125* (PCCI). F, upland forests, thickets, and margins of old fields.

Carex communis L. H. Bailey, sedge—*BSS 2023* (MICH, PCCI). O, young to mature upland forests. Collected from what was later determined to be an introduced population. Naturally occurring plants were noted as infrequent elsewhere. †YF.

Carex comosa Boott, sedge—*BSS 115*, *189* (ALBC, PCCI). F, shores, marshes, and open swamps, often in standing water.

Carex crinita Lam., sedge—*BSS 2221* (MICH, PCCI). O, mostly in and around buttonbush depressions and seasonally inundated wetlands.

Carex cristatella Britton, sedge—*BSS 2267* (PCCI). O, margins of seasonally inundated wetlands and infrequent elsewhere on moist ground.

Carex deweyana Schwein., sedge—*BSS 2097* (MICH, PCCI). O, rich upland forests.

Carex diandra Schrank, sedge—*BSS 2144* (PCCI). LC, shores of Brewster Lake and along Cedar Creek, often growing on *Carex prairea* tussocks.

Carex digitalis Willd., sedge—*BSS 2115* (MICH, PCCI). F, rich, especially oak-dominated, forests.

Carex disperma Dewey, sedge—*BSS 360* (MICH). O, cedar-tamarack swamps.

Carex gracillima Schwein., sedge—*BSS 69* (ALBC, PCCI), *326* (ALBC). C, widespread in a variety of habitats, especially prominent in weedy thickets and young forests at wetland margins.

Carex granularis Willd., sedge—*BSS 2094* (PCCI). LC, moist old fields and trails through open wetlands.

Carex grisea Wahlenb., sedge—*BSS 2199* (PCCI). F, moist, usually shaded habitats, including weedy young forests and margins of old fields.

Carex hirtifolia Mack., sedge—*BSS 2018* (PCCI). LC, rich upland forests and thickets, often on lower slopes.

Carex hitchcockiana Dewey, sedge—*BSS 2095* (MICH, PCCI). O, rich oak and beech-maple forests.

Carex hystericina Willd., sedge—*BSS 125*, *169* (ALBC, PCCI); *BSS 2283* (PCCI). C, swamp forests, wet thickets, seeps, and shores.

Carex interior L. H. Bailey, sedge—*BSS 116* (ALBC, PCCI), *2145* (PCCI). C, swamp forests, wet thickets, sedge meadows, seeps, and shores.

Carex intumescens Rudge, sedge—*BSS 2185* (PCCI). O, low hardwoods and margins of depressions and buttonbush depressions.

Carex lacustris Willd., sedge—*BSS 366*, *368* (ALBC); *BSS 2098* (PCCI). A, marshes, wet meadows, open swamps.

Carex laevivaginata (Kük.) Mack., sedge—*BSS 124* (ALBC, PCCI). O, open swamps, wet thickets, and seeps.

Carex lasiocarpa Ehrh., sedge—*BSS 2177* (PCCI). LC, open springy areas. Fertile culms sparse.

Carex laxiculmis Schwein. var. *copulata* (L. H. Bailey) Fernald, sedge—*BSS 2019* (MICH, PCCI), *2049* (PCCI). F, copses and lower slopes in rich mesic forests.

Carex laxiflora Lam., sedge—*BSS 2024* (MICH, PCCI); *BSS 2077*, *2093*, *2165* (PCCI). F, rich oak and beech-maple forests.

Carex leptalea Wahlenb., sedge—*BSS 2175* (PCCI). C, open to forested wetlands, spring runs.

Carex lupulina Willd., sedge—*BSS 2268* (PCCI). O, margins of vernal pools and seasonally inundated depressions.

Carex lurida Wahlenb., sedge—*BSS 168* (ALBC, PCCI); *BSS 2282*, *MV 18* (PCCI). C, swamp forests, wet thickets, trails through wetlands.

Carex meadii Dewey, sedge—*BSS 2228* (PCCI). R, fen-like sedge meadow N of Cloverdale Road.

Carex muehlenbergii Willd. var. *muehlenbergii*, sedge—*BSS 2226* (PCCI). R, old fields.

Carex normalis Mack., sedge—*BSS 172*, *174* (ALBC, PCCI); *BSS 2123*, *2206* (PCCI). F, forest borders, thickets, and old fields.

Carex pedunculata Willd., sedge—*BSS 2026* (PCCI). C, rich, especially beech-maple, forests; mounds and bases of trees in swamp forests.

Carex pellita Willd., sedge—*BSS 67* (ALBC, PCCI). C, wet meadows, shores, and wet thickets.

Carex pensylvanica Lam., sedge—*JDS 4027* (ALBC, PCCI). A, upland forests.

Carex plantaginea Lam., sedge—*BSS 2075* (MICH, PCCI). O, mature upland forests in small colonies.

Carex prairea Dewey, sedge—*BSS 118* (ALBC, PCCI), *327* (ALBC). F, shores, spring runs, and ± open wetlands.

Carex radiata (Wahlenb.) Small, straight-styled wood sedge—*BSS 2020* (MICH, PCCI). O, wooded copses and wetland margins.

Carex rosea Willd., curly-styled wood sedge—*BSS 2054* (PCCI). F, upland forests primarily.

Carex sartwellii Dewey, sedge—*BSS 2149* (PCCI). LC, wet meadows and fens, especially along Brewster Lake and Cedar Creek.

Carex scabrata Schwein., sedge—*BSS 2127* (MICH, PCCI). R, mucky depression at base of esker in beech-maple forest.

Carex seorsa Howe, sedge—*BSS 2202* (MICH, PCCI). LC, buttonbush depressions. **THREATENED.**

Carex sparganioides Willd., sedge—*BSS 432* (MICH). F, upland forests, including young, weedy stands, and thickets.

Carex stipata Willd., sedge—*BSS 2130* (PCCI). F, wet thickets, wetland borders, and seeps.

Carex stricta Lam., sedge—*BSS 2099* (PCCI). A, dominant in wet meadows and fens.

Carex swanii (Fernald) Mack., sedge—*BSS 2138*, *MV 2* (PCCI). C, upland forests, thickets, and margins of old fields, locally in wetter areas.

Carex tenera Dewey, sedge—*BSS 2217* (MICH, PCCI), *2222* (PCCI). LC, upland forests and old fields.

Carex tetanica Schkuhr, sedge—*BSS 2147*, *2276b* (PCCI). O, fens and springy open conifer swamps.

Carex tribuloides Wahlenb., sedge—*BSS 2269*, *2313*, *2392* (PCCI). O, moist forests and margins of seasonally ponded wetlands.

Carex trisperma Dewey, sedge—*BSS 2370* (PCCI). LC, wooded bog, Whitefish Lake.

Carex utriculata Boott., sedge—*BSS 190* (ALBC, PCCI); *BSS 334* (MICH); *BSS 2129*, *2170* (PCCI). C, open swamps, wet meadows, marshes, and shores.

Carex vulpinoidea Michx., sedge—*BSS 2215*, *MV 9* (PCCI). C, open areas generally, especially along trails.

Carex woodii Dewey, sedge—*BSS 2096* (PCCI). LC, rich upland forests, often on lower slopes.

Cyperus bipartitus Kunth, brook nut sedge—*BSS 236* (ALBC, PCCI). O, shores and margins of Cloverdale Road.

Cyperus esculentus L., yellow nutsedge—*BSS 2434* (PCCI). R, disturbed sandy ground next to Prairie View.

Cyperus lupulinus (Spreng.) Marcks, slender sand sedge—*JDS 4051* (ALBC, PCCI). LC, disturbed, open sandy ground.

Cyperus strigosus L., long scaled nut sedge—*BSS 237* (ALBC, PCCI), *2484* (PCCI), *2532* (MICH). O, shores and recently disturbed open ground.

Dulichium arundinaceum (L.) Britton, three-way sedge—*BSS 2352* (PCCI). O, springy openings; margins of wooded bog, Whitefish Lake.

Eleocharis erythropoda Steud., spike-rush—*BSS 119* (ALBC, PCCI). LC, shores.

Eleocharis elliptica Kunth, golden-seeded spike rush—*BSS 2343* (MICH, PCCI). LC, fen-like sedge meadow N of Cloverdale Road.

Eleocharis obtusa (Willd.) Schult., spike rush—*BSS 2391* (PCCI). O, dried bottoms of seasonally inundated ± open wetlands.

Eleocharis palustris (L.) Roem. & Schult., spike-rush—*BSS 123* (ALBC, PCCI). LC, shores.

Eriophorum gracile W. D. J. Koch, slender cotton-grass—*BSS 2182* (MICH, PCCI). R, springy opening within cedar-tamarack swamp.

Schoenoplectus acutus (Bigelow) Á. Löve & D. Löve, hardstem bulrush—*BSS 135* (ALBC, PCCI). F, open wetlands, shores, and shallow water in lakes and Cedar Creek.

Schoenoplectus tabernaemontani (C. C. Gmel.) Palla, softstem bulrush—*BSS 2257*, *2376* (PCCI). O, open wetlands, especially springs and shores.

Scirpus atrovirens Willd., bulrush—*BSS 137* (ALBC, PCCI), *2413* (PCCI). F, sedge meadows, shores, springy openings.

Scirpus cyperinus (L.) Kunth, wool-grass—*BSS 454* (ALBC). O, shores, seasonally ponded wetlands.

Scirpus pendulus Muhl., bulrush—*BSS 213* (ALBC, PCCI). O, disturbed moist ground along trails through wetlands.

DIOSCOREACEAE

Dioscorea villosa L., wild yam—*BSS 405* (ALBC), *EA s.n.* (PCCI). F, forests, thickets, and borders, wet or dry.

HEMEROCALLIDACEAE – see ASPHODELACEAE

HYDROCHARITACEAE

Elodea canadensis Michx., common waterweed—*BSS 2482* (PCCI). LC, Cedar Creek.

Elodea nuttallii (Planch.) H. St. John, slender waterweed— *BSS 2350* (PCCI), *JDS 4071* (ALBC, PCCI). LC, near dock on E shore of Brewster Lake.

Najas guadalupensis (Spreng.) Magnus, southern naiad—*BSS 2516* (PCCI). LC, Aurohn Lake.

HYPOXIDACEAE

Hypoxis hirsuta (L.) Coville, star-grass—*BSS 2227* (PCCI). R, local in fen-like sedge meadow N of Cloverdale Road.

IRIDACEAE

**Iris germanica* L., flag—*BSS 106* (ALBC, PCCI). R, along Cloverdale Road near entrance to Beech Maple Ridge Trail, where spreading locally.

Iris virginica L., southern blue flag—*BSS 110* (ALBC, PCCI). C, shores, marshes, seeps, and other wet places.

JUNCACEAE

Juncus acuminatus Michx., sharp-fruited rush—*BSS 455* (ALBC), *2334* (PCCI). O, open wetlands, moist fields.

Juncus brachycephalus (Engelm.) Buchenau, rush—*BSS 238* (ALBC, PCCI), *2528* (MICH, PCCI). R, seep and adjacent roadside E of Brewster Lake.

Juncus dudleyi Wiegand, Dudley's rush—*BSS 2278* (PCCI). R, widely distributed in low numbers in wetlands, but perhaps overlooked.

Juncus effusus L., soft-stemmed rush—*BSS 456* (ALBC). O, shores, open wetlands, moist areas in fields.

Juncus nodosus L., joint rush—*BSS 2535* (MICH, PCCI). R, gravelly shoulder of Cloverdale Road.

Juncus tenuis Willd., path rush—*BSS 173*, *JDS 4033* (ALBC, PCCI). F, moist disturbed ground throughout.

Luzula multiflora (Ehrh.) Lej., common wood rush—*BSS 2025* (PCCI), *2045* (MICH). O, rich oak and beech-maple forests, dry banks.

JUNCAGINACEAE

Triglochin maritima L., common bog arrow-grass—*BSS 2181* (PCCI). LC, springy openings in cedar-tamarack swamps.

Triglochin palustris L., slender bog arrow-grass—*BSS 196* (ALBC, PCCI). R, shoreline fen, Brewster Lake.

LILIACEAE

Erythronium americanum Ker Gawl., yellow trout lily—*BSS 45* (ALBC, PCCI). C, upland forests (especially beech-maple stands) and thickets.

Lilium michiganense Farw., Michigan lily—*BSS 171* (ALBC, PCCI). F, open swamps, wet thickets, sedge meadows, shores.

MELANTHIACEAE

Trillium grandiflorum (Michx.) Salisb., common trillium—*BSS 25* (ALBC, PCCI). F, rich upland forests, occasional in swamps. Flowering plants especially occur in greater abundance at present (see Slaughter and Skean 2003a).

ORCHIDACEAE

Calopogon tuberosus (L.) Britton, Sterns & Poggenb., grass-pink—*BSS 2273* (PCCI). R, springy open cedar-tamarack swamp.

Corallorhiza maculata Raf., spotted coral-root—*JDS 4087* (ALBC, PCCI). R, mature oak forest.

Corallorhiza odontorhiza (Willd.) Nutt. var. *pringlei* (Greenm.) Freudenst., fall coral-root—*BSS 2417* (PCCI). R, along Cedar Creek Trail on wooded bank above Cedar Creek.

Cypripedium acaule Aiton, pink lady-slipper—*BSS 2366* (PCCI). LC, wooded bog, Whitefish Lake.

Cypripedium parviflorum Salisb. var. *makasin* (Farw.) Sheviak, northern yellow lady-slipper—*BSS 66* (ALBC, PCCI). O, open swamps and wet thickets, formerly frequent (see Slaughter & Skean 2003a).

Cypripedium parviflorum Salisb. var. *pubescens* (Willd.) O. W. Knight, large yellow lady-slipper—*BSS 87* (ALBC, PCCI). R, same habitats as var. *makasin* but more often in open sedge meadows; not observed in 2018.

Cypripedium reginae Walter, showy lady-slipper—*BSS 136* (ALBC, PCCI). O, open swamp forests, wet thickets, shores. Formerly on tussocks on shore of Brewster Lake (now destroyed by beaver impoundment).

**Epipactis helleborine* (L.) Crantz, helleborine—*BSS 429* (MICH). O, widely scattered in a variety of habitats.

Malaxis monophyllos (L.) Sw. subsp. *brachypoda* Á. Löve & D. Löve, white adder's-mouth—*BSS 2277* (MICH, PCCI). R, springy open cedar-tamarack swamp.

Platanthera clavellata (Michx.) Luer, club-spur orchid—*BSS 465* (ALBC), *479* (MICH). O, swamp forests.

Platanthera psycodes (L.) Lindl., purple fringed orchid—*BSS 466* (photographic documentation, ALBC). O, open swamps, wet thickets.

Spiranthes cernua (L.) Rich., nodding ladies'-tresses—*BSS 268* (ALBC, PCCI). LC, shoreline fen, Brewster Lake; current status unknown. Pace and Cameron (2017) split plants of the glaciated Midwestern and Northeastern United States and Canada as *Spiranthes incurva* (Jenn.) M. C. Pace.

Spiranthes lucida (H. H. Eaton) Ames, shining ladies'-tresses—*BSS 108* (ALBC, PCCI). R, shores and disturbed open mucky ground.

POACEAE

**Agrostis gigantea* Roth, redtop—*BSS 164*, *167* (ALBC, PCCI). F, old fields, thickets, open wetlands, and disturbed open ground.

Agrostis perennans (Walter) Tuck., autumn bent—*BSS 2490* (PCCI). O, upland forests, swamps, and borders.

Agrostis scabra Willd., ticklegrass—*BSS 2308* (PCCI). F, old fields and disturbed open ground.

**Agrostis stolonifera* L., creeping bent—*BSS 146b*, *181* (ALBC, PCCI). R, gravel parking lot, Beech Maple Ridge Trail.

Andropogon gerardii Vitman, big bluestem—*BSS 2472* (PCCI). Widespread and abundant in prairie plantings; O as waifs or naturally occurring clumps along Cloverdale Road and elsewhere. †HP, LT, ME, MW, N, NE, NW, SE1, SE2, SW.

Andropogon virginicus L., broom-sedge—*BSS 314* (ALBC, PCCI), *2477* (MICH, PCCI). LC, old fields and clearings on sandy soil.

Anthoxanthum hirtum (Schrank) Y. Schouten & Veldkamp, sweet grass—*BSS 114* (ALBC, PCCI). O, sedge meadows.

**Arrhenatherum elatius* (L.) J. Presl & C. Presl, tall oatgrass—*BSS 113* (ALBC, PCCI), *2188* (PCCI), *JF s.n.* (PCCI). LC, N side of Cloverdale Road and adjacent old field opposite Research Lab.

Brachyelytrum erectum (Roth) P. Beauv., long-awned wood grass—*BSS 2380* (MICH, PCCI); *BSS 2445*, *MV 20* (PCCI). F, rich upland forests.

Bromus ciliatus L., fringed brome—*BSS 2323* (PCCI), *JDS 4059a* (ALBC, PCCI). F, sedge meadows, shores, wet thickets, open swamps.

**Bromus hordeaceus* L., soft brome—*BSS 2065* (MICH, PCCI), *2155* (PCCI). F, open, disturbed ground, especially in prairie plantings, near buildings, and along trails.

**Bromus inermis* Leyss., smooth brome—*BSS 112* (ALBC, PCCI); *JF s.n.*, *MV 7* (PCCI). C, old fields, roadsides, thickets, and forest borders, persisting in weedy young forests.

Bromus latiglumis (Shear) Hitchc., ear-leaved brome—*BSS 259* (ALBC, PCCI). O, thickets and swamp borders.

Bromus nottowayanus Fernald, satin brome—*BSS 2310* (MICH, PCCI). O, mature beech-maple and oak forests.

Bromus pubescens Willd., Canada brome—*MB s.n.* (PCCI). Not observed in 2018 survey; abundance unknown; collection may be from introduced plants. †WOOD.

**Bromus tectorum* L., cheat grass—*BSS 2039* (PCCI). R, recently disturbed open ground near Prairie View.

Calamagrostis canadensis (Michx.) P. Beauv., blue-joint—*BSS 219*, *JDS 4063* (ALBC, PCCI). C, sedge meadows, wet thickets, open swamps, and shores.

Cinna arundinacea L., wood reedgrass—*BSS 2466* (PCCI). †WOOD. C, swamps, wet thickets, and shores; occasional in upland forests.

**Dactylis glomerata* L., orchard grass—*BSS 111* (ALBC, PCCI), *MW s.n.* (PCCI). C, old fields, thickets, borders, and weedy forests; along trails in less disturbed habitats.

Danthonia spicata (L.) Roem. & Schult., poverty grass—*JDS 4032* (ALBC, PCCI). O, upland forests (especially on banks and along trails) and disturbed sandy ground. †SP.

Dichanthelium clandestinum (L.) Gould, panic grass—*BSS 2353* (MICH, PCCI). R, upland/swamp forest ecotone near terminus of Cedar Creek Trail.

Dichanthelium columbianum (Scribn.) Freckmann, panic grass—*BSS 2157* (PCCI). LC, sandy old field near terminus of Cedar Creek Trail.

Dichanthelium depauperatum (Muhl.) Gould, panic grass—*BSS 2156* (PCCI). LC, sandy old field near terminus of Cedar Creek Trail.

Dichanthelium dichotomum (L.) Gould, panic grass—*BSS 2359* (PCCI). O, upland forests, especially banks and along trails.

Dichanthelium implicatum (Scribn.) Kerguélen, panic grass—*BSS 2233*, *2244*, *2251*, *2357* (PCCI). F, upland forests, thickets, old fields, and prairie plantings. Variable.

Dichanthelium latifolium (L.) Harvill, broad-leaved panic grass—*BSS 2280* (PCCI). R, disturbed oak forest behind Research Lab.

Dichanthelium linearifolium (Britton) Gould, slender-leaved panic grass—*BSS 2161* (MICH, PCCI). R, sandy old field near terminus of Cedar Creek Trail.

Dichanthelium lindheimeri (Nash) Gould, panic grass—*BSS 2162* (PCCI). O, sandy old field near terminus of Cedar Creek Trail.

Dichanthelium oligosanthes (Schult.) Gould subsp. *scribnerianum* (Nash) Freckmann & Lelong, panic grass—*BSS 2112*, *MV 19* (PCCI); *BSS 2158* (MICH). O, old fields and margins of prairie plantings, often in loose, sandy soil.

Digitaria cognata (Schult.) Pilg., fall witch grass—*BSS 315* (ALBC, PCCI), *2305* (PCCI). F, disturbed open ground, especially sandy old fields and prairie plantings.

**Digitaria ischaemum* (Schreb.) Muhl., smooth crab grass—*BSS 241* (ALBC, PCCI). C, disturbed open ground.

**Digitaria sanguinalis* (L.) Scop., hairy crab grass—*BSS 2304* (MICH, PCCI). F, disturbed open ground.

**Echinochloa crusgalli* (L.) P. Beauv., barnyard grass—*JDS 4065* (ALBC, PCCI). LC, disturbed open ground.

Echinochloa muricata (P. Beauv.) Fernald, barnyard grass—*BSS 220* (ALBC, PCCI). LC, recently disturbed open ground.

**Eleusine indica* (L.) Gaertn., goose grass—*BSS 2330* (PCCI). O, disturbed, open ground, especially on compacted soils.

Elymus hystrix L., bottlebrush grass—*BSS 2218* (PCCI). F, upland forests (including weedy young stands), thickets, and wetland borders. †WOOD, SE1.

**Elymus repens* (L.) Gould, quack grass—*BSS 146a*, *JDS 4053* (ALBC, PCCI); *EA s.n.*, *MV 1*, *MV 3* (PCCI). C, old fields, thickets, borders, and elsewhere on disturbed open ground.

Elymus riparius Wiegand, riverbank wild-rye—*JDS 4067* (ALBC, PCCI). O, open swamps, wet thickets, sedge meadows, and shores.

Elymus trachycaulus (Link) Gould, slender wheatgrass—*JDS 4059b* (ALBC, PCCI). O, widely distributed in low numbers in wetlands, oak forests, and banks.

Elymus villosus Willd., silky wild-rye—*BSS 161* (ALBC, PCCI), *JF s.n.* (PCCI). F, upland forests, thickets, and swamp borders. †WOOD.

Elymus virginicus L., Virginia wild-rye—*BSS 2480* (MICH, PCCI). O, apparently restricted or nearly restricted to sedge tussocks along Cedar Creek. †HP, WOOD.

**Eragrostis cilianensis* (All.) Janch., stink grass—*BSS 2327* (MICH, PCCI). O, parking lots, sidewalks, and open, disturbed soil, including margins of prairie plantings.

**Eragrostis minor* Host, low love grass—*BSS 179* (ALBC, PCCI). O, parking lots, sidewalks, and open, compacted ground.

Eragrostis pectinacea (Michx.) Nees, love grass—*BSS 2432* (MICH, PCCI). LC, disturbed open ground, including dry retention basins.

Eragrostis spectabilis (Pursh) Steud., purple love grass—*BSS 2427* (PCCI). LC, sandy old fields/prairie plantings.

**Festuca rubra* L., red fescue—*BSS 2232* (PCCI), *JDS 4037* (ALBC, PCCI). O, recently disturbed open ground.

Festuca subverticillata (Pers.) E. B. Alexeev, nodding fescue—*BSS 212* (ALBC, PCCI), *2143* (PCCI). C, upland forests.

Glyceria septentrionalis Hitchc., floating manna grass—*BSS 2406* (PCCI). LC, dried marsh bottom E of Hyla House, S of Cloverdale Road.

Glyceria striata (Lam.) Hitchc., fowl manna grass—*BSS 439* (ALBC), *2266* (PCCI). C, swamps, wet thickets, open wetlands, shores; low areas in upland forests. †WOOD.

**Holcus lanatus* L., velvet grass—*JDS 4036* (ALBC, PCCI). R, disturbed sandy ground N of Batts Cottage.

Leersia oryzoides (L.) Sw., cut grass—*BSS 264* (ALBC, PCCI). C, shores, marshes, sedge meadows, wet thickets, and open swamps.

Leersia virginica Willd., white grass—*BSS 2426* (MICH, PCCI). F, moist forests, swamp borders, shaded trails.

**Lolium arundinaceum* (Schreb.) Darbysh., tall fescue—*BSS 2140* (MICH, PCCI). C, old fields.

**Lolium perenne* L., ryegrass—*BSS 2154* (PCCI). R, recently disturbed open ground.

***Lolium pratense* (Huds.) Darbysh., meadow fescue—*BSS 180* (ALBC, PCCI), *2389* (PCCI). O, roadsides, old fields, disturbed open ground.

Milium effusum L., wood millet—*BSS 346* (MICH). F, swamp forests and occasionally upland forests.

Muhlenbergia frondosa (Poir.) Fernald, common satin grass—*BSS 2461* (MICH, PCCI). O, ± shaded trails and roadsides.

Muhlenbergia mexicana (L.) Trin., leafy satin grass—*BSS 2481* (MICH, PCCI). F, sedge meadows, wet thickets, open swamps, and shores.

Muhlenbergia schreberi J. F. Gmel., nimblewill—*BSS 2443* (MICH, PCCI). F, dense colonies scattered along ± shaded trails.

Muhlenbergia sylvatica Torr., woodland satin grass—*BSS 2465* (MICH, PCCI). F, open swamps and borders.

Panicum capillare L., witch grass—*BSS 2541* (PCCI). LA, locally abundant in large dense colonies on recently disturbed open ground, along roads, etc.

Panicum dichotomiflorum Michx., panic grass—*BSS 240* (ALBC, PCCI), *2439* (PCCI), *2500* (MICH). LC, recently disturbed open ground and roadsides.

Panicum gattingeri Nash, panic grass—*BSS 239* (ALBC, PCCI). R, moist thicket along Cloverdale Road.

Panicum virgatum L., switch grass—*BSS 2437* (PCCI). Abundant in plantings; away from plantings, O, roadsides and dry open ground, perhaps only as waifs from introduced populations. †HP, ME, MW, N, NW, SE1, SW.

Paspalum setaceum Michx. var. *stramineum* (Nash) D. J. Banks, hairy lens grass—*BSS 2495* (PCCI). LC, dry old field behind Research Lab.

**Phalaris arundinacea* L., reed canary grass—*BSS 2167* (PCCI). O, disturbed wetlands and shores.

**Phleum pratense* L., timothy—*BSS 138* (ALBC, PCCI); *EA s.n.*, *MV 10* (PCCI). C, roadsides, old fields, thickets and borders.

Phragmites australis (Cav.) Steud. subsp. *americanus* Saltonst., P. M. Peterson & Soreng, reed—*BSS 2494* (MICH, PCCI). C, forming large colonies in marshes and swamp borders along and near Cedar Creek. The number and aerial extent of colonies have apparently increased in recent years (Poyner et al. 2014), although the plants in these colonies are morphologically consistent with the native subspecies.

**Phragmites australis* (Cav.) Steud. subsp. *australis*, reed—*BSS 242* (ALBC, PCCI), *2527* (MICH). LC, one large colony and several smaller patches along Cloverdale Road, W of Brewster Lake Trail.

Poa alsodes A. Gray—*BSS 81*, *101* (ALBC, PCCI). F, mature upland forests.

**Poa annua* L., annual bluegrass—*BSS 2010* (PCCI). C, compacted soils, in the open and in shade, as on trails, lawns, and near buildings.

**Poa compressa* L., Canada bluegrass— *EA s.n.*, *MB s.n.* (PCCI); *JDS 4038* (ALBC, PCCI). C, weedy young forests, thickets, trails, and disturbed dry ± shaded ground generally.

Poa languida Hitchc., bluegrass—*BSS 2117* (MICH, PCCI). O, mature upland forests.

Poa paludigena Fernald & Wiegand, bog bluegrass—*BSS 2178* (MICH, PCCI). F, springy open swamps, seepages, and along spring runs. **THREATENED**.

**Poa pratensis* L., Kentucky bluegrass—*BSS 62*, *166* (ALBC, PCCI), *2041* (PCCI), *2148* (MICH, PCCI). C, old fields, prairie plantings, thickets, and disturbed open ground generally, including wet areas.

Poa sylvestris A. Gray, woodland bluegrass—*BSS 2116* (MICH, PCCI). F, mature upland forests.

**Poa trivialis* L., bluegrass—*BSS 2132* (MICH, PCCI), *2150* (PCCI). O, borders of old fields and thickets; compacted soil on trails. Easily overlooked.

Schizachne purpurascens (Torr.) Swallen, false melic—*BSS 2198* (MICH, PCCI). LC, toeslope in beech-maple forest.

Schizachyrium scoparium (Michx.) Nash, little bluestem—*BSS 2534* (PCCI). R as a local waif from plantings. †HP, LT, ME, MW, NE, NW, SE1, SE2, SP, SW.

**Setaria faberi* Herrm., giant foxtail—*BSS 2429*, *2502* (PCCI); *BSS 2433* (MICH, PCCI). LA, locally abundant in large dense colonies on recently disturbed open ground.

**Setaria pumila* (Poir.) Roem. & Schult., yellow foxtail—*JDS 4064a* (ALBC, PCCI). F, old fields, roadsides, recently disturbed open ground.

**Setaria viridis* (L.) P. Beauv., green foxtail—*JDS 4064b* (ALBC, PCCI). O, old fields, roadsides, recently disturbed open ground.

Sorghastrum nutans (L.) Nash, Indian grass—*BSS 2479* (PCCI). Introduced in several prairie plantings; as a presumably naturally occurring species, R, margins of sandy old field near terminus of Cedar Creek Trail, where noted by T. Bassett prior to seedings. †HP, ME, MW, N, NW, SE1, SW.

Spartina pectinata Link, cordgrass—*BSS 216*, *JDS 4066* (ALBC, PCCI). LC, sedge meadows near and along Cloverdale Road. †HP, ME, MW, SE1, SW.

Sphenopholis intermedia (Rydb.) Rydb., slender wedgegrass—*BSS 2184*, *2255* (PCCI). F, widespread in a variety of upland and wetland habitats, but typically in small populations.

Sphenopholis nitida (Biehler) Scribn., shining wedgegrass—*BSS 2360* (PCCI). R, dry wooded bank above Whitefish Lake.

Sporobolus vaginiflorus (A. Gray) Alph. Wood, sheathed rush grass—*BSS 2478* (PCCI). R, eroded sandy soils and compacted gravelly soil along Cloverdale Road. Perhaps overlooked elsewhere.

Torreyochloa pallida (Torr.) G. L. Church, pale false mannagrass—*BSS 2369* (PCCI). R, lagg at margin of wooded bog, Whitefish Lake.

Tridens flavus (L.) Hitchc., purpletop—*BSS 2476* (PCCI). O, widely scattered in low numbers in old fields and roadsides.

**Triticum aestivum* L., wheat—*BSS 2262* (PCCI). R, recently disturbed open ground near Prairie View.

**Zea mays* L., maize—*BSS 2530* (PCCI). R, waif along Cloverdale Road.

Zizania aquatica L., southern wild-rice—*BSS 2497* (MICH, PCCI). R, several small patches on shallowly inundated muck flats along Cedar Creek. **THREATENED.**

PONTEDERIACEAE

Pontederia cordata L., pickerel-weed—*BSS 2361* (PCCI). LC, shallow water, Whitefish Lake.

POTAMOGETONACEAE

Potamogeton amplifolius Tuck., large-leaved pondweed—*BSS 2363* (PCCI). LC, Brewster and Whitefish Lakes.

Potamogeton berchtoldii Fieber, pondweed—*BSS 2483* (MICH). LC, Brewster and Whitefish Lakes and Cedar Creek.

**Potamogeton crispus* L., pondweed—*BSS 2485* (PCCI). R, one small colony noted in Cedar Creek SW of terminus of Cedar Creek Trail.

Potamogeton friesii Rupr., Fries's pondweed—*BSS 2341* (PCCI). LC, Brewster and Whitefish Lakes and Cedar Creek.

Potamogeton illinoensis Morong, Illinois pondweed—*BSS 2346* (PCCI), *JDS 4072* (ALBC, PCCI). LC, Brewster Lake.

Potamogeton nodosus Poir., pondweed—*BSS 2489* (PCCI). LC, Cedar Creek.

Potamogeton pulcher Tuck., spotted pondweed—*BSS 2450* (PCCI), *2523* (MICH). LC, lagg around bog and shrub swamp, Whitefish Lake. **ENDANGERED.**

Stuckenia pectinata (L.) Börner, sago pondweed—*BSS 2253*, *2340*, *2488*, *2491* (PCCI). LC, Brewster Lake, Cedar Creek.

SMILACACEAE

Smilax hispida Raf., bristly greenbrier—*BSS 2052* (MICH, PCCI). C, young forests, borders, and thickets, often in weedy areas.

TRILLIACEAE – see MELANTHIACEAE

TYPHACEAE

Sparganium americanum Nutt., American bur-reed—*BSS 2336* (MICH, PCCI). F, marshes and shores.

Sparganium emersum Rehm., green-fruited bur-reed—*BSS 2486* (PCCI). LC, Cedar Creek.

Sparganium eurycarpum Engelm., common bur-reed—*BSS 191* (ALBC, PCCI). F, marshes and shores.

**Typha angustifolia* L., narrow-leaved cat-tail—*BSS 2321* (PCCI). LC, beaver-impounded drainage S of Brewster Lake and Cloverdale Road, and local elsewhere (see Huisman et al. 2012).

**Typha* ×*glauca* Godr., hybrid cat-tail—*BSS 2349* (PCCI). O, collected from peat island along shore of Brewster Lake; sporadically distributed. See Huisman et al. (2012).

Typha latifolia L., common cat-tail—*BSS 200* (ALBC, PCCI). C, the most widespread and abundant *Typha* on the property, forming stands on shores and especially marshes near Cedar Creek.

CERATOPHYLLALES

CERATOPHYLLACEAE

Ceratophyllum demersum L., coontail—*BSS 2339* (PCCI). LC, dense masses in Brewster and Aurohn Lakes.

Ceratophyllum echinatum A. Gray, spiny hornwort—*BSS 2373* (PCCI), *2451* (MICH). LA, dense masses in bog lagg, Whitefish Lake.

EUDICOTS

ADOXACEAE

Sambucus canadensis L., common elder—*BSS 2246* (PCCI). C, wetlands and wetland borders, occasionally in uplands.

Sambucus racemosa L., red-berried elder—*BSS 2016* (PCCI). O, wetland borders and on tipped-up tree bases in upland forests, where protected from browse; sporadically distributed.

Viburnum acerifolium L., maple-leaved viburnum—*BSS 2124* (PCCI). F, rich upland forests.

Viburnum lentago L., nannyberry—*BSS 59*, *JDS 4081* (ALBC, PCCI); *BSS 480*, *JDS 4234* (ALBC); *MV 15* (PCCI). C, open swamps and wet thickets.

Viburnum rafinesquianum Schult., downy arrowwood. *JDS 4239* (ALBC). O, dry thickets.

Viburnum trilobum Marshall, American highbush-cranberry—*BSS 2186* (PCCI). R, shrub-carr along small tributary to Cedar Creek; potentially overlooked.

AMARANTHACEAE

Amaranthus albus L., tumbleweed—*BSS 2329* (MICH, PCCI). R, open, raw ground.

**Amaranthus powellii* S. Watson, tall amaranth—*BSS 2438* (PCCI). LC, open, raw ground.

**Amaranthus retroflexus* L., rough amaranth—*BSS 2331* (MICH, PCCI). LC, open, raw ground.

**Chenopodium album* L., lambs-quarters—*BSS 2428* (PCCI). F, waste areas and recently disturbed ground.

Chenopodium simplex Raf., maple-leaved goosefoot—*BSS 2388* (MICH, PCCI). R, waste area behind Hyla House.

ANACARDIACEAE

Rhus copallina L., shining sumac—*BSS 2139* (PCCI). LC, old field and thicket S of Aurohn Lake.

Rhus typhina L., staghorn sumac—*BSS 279* (ALBC, PCCI). O, roadsides, thickets, borders.

Toxicodendron radicans (L.) Kuntze, poison-ivy—*JDS 4041* (ALBC, PCCI). A, widespread throughout in all but the wettest habitats.

Toxicodendron vernix (L.) Kuntze, poison sumac—*BSS 198*, *285* (ALBC, PCCI). C, wetlands throughout.

APIACEAE

Angelica atropurpurea L., purplestem angelica—*BSS 141* (ALBC, PCCI). F, sedge meadows, wet thickets, and marshes, especially near Cedar Creek.

Cicuta bulbifera L., water hemlock—*BSS 195* (ALBC, PCCI). C, shores, spring runs, wet meadows.

Cicuta maculata L., water hemlock—*BSS 170* (ALBC, PCCI), *407* (ALBC). F, open swamps, wet thickets, sedge meadows, and shores.

Cryptotaenia canadensis (L.) DC., honewort—*BSS 410* (ALBC, PCCI), *EA s.n.* (PCCI). F, swamps, moist forests, thickets. †WOOD.

***Daucus carota* L., Queen-Anne's-lace—*BSS 183* (ALBC, PCCI), *MV 25* (PCCI). F, old fields, prairie plantings, roadsides, and disturbed open ground generally.

Erigenia bulbosa (Michx.) Nutt., harbinger-of-spring—*BSS 2076* (MICH, PCCI). LC, small, dense colonies in isolated wooded copse surrounded by swamp forest.

Osmorhiza claytonii (Michx.) C. B. Clarke, hairy sweet-cicely—*BSS 90b* (ALBC, PCCI), *2192* (PCCI). O, mature upland forests, less weedy than *Osmorhiza longistylis*. †WOOD.

Osmorhiza longistylis (Torr.) DC., smooth sweet-cicely—*BSS 90a* (ALBC, PCCI); *BSS 2121*, *JF s.n.* (PCCI). O, infrequent to locally common in moist, weedy young forests.

Oxypolis rigidior (L.) Raf., cowbane—*BSS 482* (ALBC). O, open swamps, buttonbush depressions, wet thickets, sedge meadows, and shores.

Sanicula canadensis L., black snakeroot—*BSS 2270* (MICH), *2356* (PCCI). R, rich upland forests and moist fields.

Sanicula odorata (Raf.) Pryer & Phillippe, black snakeroot—*BSS 163*, *JDS 4086* (ALBC, PCCI); *BSS 381*, *424* (ALBC); *JF s.n.* (PCCI). A, throughout in shaded habitats, especially weedy young forests.

Sanicula trifoliata E. P. Bicknell, black snakeroot—*BSS 2314* (PCCI). R, rich upland forests.

Sium suave Walter, water-parsnip—*BSS 2435* (MICH, PCCI). O, exposed bottoms of seasonally inundated depressions.

Taenidia integerrima (L.) Drude, yellow-pimpernel—*BSS 2086* (MICH, PCCI). LC, dry, semi-shaded bank above Cedar Creek. †WOOD.

***Torilis japonica* (Houtt.) DC., hedge-parsley—*BSS 2316* (MICH, PCCI). O, old fields, thickets, weedy young forests.

Zizia aurea (L.) W. D. J. Koch, golden alexanders—*BSS 58* (ALBC, PCCI). O, sedge meadows and shores. †MW, N, NE, SE2. [*JS 3*, PCCI].

APOCYNACEAE

Apocynum cannabinum L., Indian-hemp—*BSS 204a* (ALBC, PCCI). C, widespread in a variety of wet to dry, usually open, habitats; persisting locally in shade. †ME, MW, SE1, SW.

Asclepias exaltata L., poke milkweed—*BSS 2258* (PCCI). O, upland (mostly oak) forests. †WOOD.

Asclepias incarnata L., swamp milkweed—*BSS 199*, *JDS 4082* (ALBC, PCCI). C, sedge meadows, wet thickets, open swamps, shores, and springs. †HP, MON, POND, SE1.

Asclepias syriaca L., common milkweed—*BSS 144* (ALBC, PCCI). F, all but the wettest and most shaded habitats. †HP, MON, NE, SP.

Asclepias tuberosa L., butterfly-weed—*BSS 2302* (PCCI). R as a naturally occurring species, along Cedar Creek Trail on S part of property. †HP, LT, ME, MON, MW, N, NE, NW, SE1, SE2, SP, SW. [*MV 24*, PCCI].

Asclepias verticillata L., whorled milkweed—*BSS 2496* (MICH, PCCI). LC, dry old field behind Research Lab. †MON, SP.

AQUIFOLIACEAE

Ilex mucronata (L.) M. Powell, V. Savolainen & S. Andrews, mountain holly—*BSS 2507* (PCCI). R, wooded bog, Whitefish Lake.

Ilex verticillata (L.) A. Gray, Michigan holly—*BSS 2219* (PCCI). F, open swamp forests, buttonbush depressions, and Whitefish Lake bog.

ARALIACEAE

Aralia nudicaulis L., wild sarsaparilla—*BSS 478* (ALBC). R, cedar swamp.

Hydrocotyle americana L., water-pennywort—*BSS 2254* (MICH, PCCI). O, wet shores.

Panax trifolius L., dwarf ginseng—*BSS 26* (ALBC, PCCI). C, mature upland forests.

ASTERACEAE

Achillea millefolium L., yarrow—*BSS 132* (ALBC, PCCI). O, old fields, thickets, clearings in wooded areas. †HP.

Ageratina altissima (L.) R. M. King & H. Rob., white snakeroot—*BSS 2463* (PCCI). O, swamps and wet thickets. †WOOD.

Ambrosia artemisiifolia L., common ragweed—*JDS 4050* (ALBC, PCCI). C, old fields, prairie plantings, waste areas, etc.

Ambrosia trifida L., giant ragweed—*BSS 2431* (MICH, PCCI). C, forest borders, thickets, old fields, and waste areas.

Antennaria howellii Greene subsp. *neodioica* (Greene) small pussytoes, cat's foot—*BSS 2081* (MICH, PCCI). LC, sandy old field near terminus of Cedar Creek Trail.

Antennaria parlinii Fernald subsp. *fallax* (Greene) Bayer & Stebbins, smooth pussytoes—*BSS 2042* (PCCI). O, old fields and margins of weedy young forests.

**Anthemis arvensis* L., corn chamomile—*BSS 2103* (PCCI). R, old fields and along trails near the Education and Prairie View buildings.

**Arctium minus* Bernh., common burdock—*BSS 2324* (MICH, PCCI). F, disturbed open ground, thickets, borders, and waste areas.

**Artemisia vulgaris* L., mugwort—*BSS 2642* (MICH, PCCI). R, old field near main campus.

**Bellis perennis* L., English daisy—*BSS 2493* (MICH, PCCI). LC, lawn, Batts Cottage.

Bidens cernua L., nodding beggar-ticks—*BSS 471* (ALBC). C, shores, drainages, and open, springy places, often in abundance.

Bidens comosa (A. Gray) Wiegand, swamp tickseed—*BSS 2458* (MICH, PCCI). O, borders of seasonally inundated depressions.

Bidens connata Muhl., purple-stemmed tickseed—*BSS 2487* (PCCI), *2524* (MICH, PCCI). O, shores, borders of seasonally inundated depressions. *BSS 2487* is f. *anomala* (Farw.) E. G. Voss, distinguished by antrorsely barbed awns.

Bidens discoidea (Torr. & A. Gray) Britton, swamp beggar-ticks—*BSS 2459* (MICH, PCCI). O, borders of seasonally inundated depressions.

Bidens frondosa L., common beggar-ticks—*BSS 2462* (PCCI). F, open swamps, wet thickets.

Bidens trichosperma (Michx.) Britton, tickseed-sunflower—*BSS 262*, *271* (ALBC, PCCI); *BSS 387*, *421* (ALBC). C, open swamps, wet thickets, sedge meadows, shores, and seeps.

Bidens vulgata Greene, tall beggar-ticks—*BSS 2460* (MICH, PCCI). R, dried marsh bottom E of Hyla House.

**Centaurea stoebe* L., spotted knapweed—*BSS 214*, *JDS 4035* (ALBC, PCCI). C, old fields, roadsides, borders, and disturbed open ground generally.

**Chondrilla juncea* L., skeleton-weed—*BSS 2449* (PCCI). LC, dry old fields S of Aurohn Lake.

**Cichorium intybus* L., chicory—*BSS 178* (ALBC, PCCI). F, old fields, roadsides, disturbed open ground.

**Cirsium arvense* (L.) Scop., Canada thistle—*BSS 158* (ALBC, PCCI). O, roadsides and disturbed clearings.

Cirsium muticum Michx., swamp thistle—*BSS 255* (ALBC, PCCI). F, open swamps, wet thickets, sedge meadows, seeps, and shores.

**Cirsium vulgare* (Savi) Ten., bull thistle—*BSS 233* (ALBC, PCCI). O, old fields, thickets, borders, and disturbed open ground generally.

Conyza canadensis (L.) Cronq., horseweed—*BSS 470* (ALBC). C, old fields, prairie plantings, and disturbed open ground generally.

**Crepis capillaris* (L.) Wallr., hawk's beard—*BSS 2131* (PCCI), *2243* (MICH). LC, old fields and prairie plantings near main campus.

Doellingeria umbellata (Mill.) Nees, flat-topped white aster—*BSS 231* (ALBC, PCCI). F, upland and wetland habitats, especially in ecotones.

Erechtites hieraciifolius (L.) Raf., fireweed—*BSS 2457* (PCCI). O, disturbed open ground and margins of dried wetland depressions.

Erigeron annuus (L.) Pers., daisy fleabane—*BSS 235* (ALBC, PCCI), *BSS 472* (ALBC), *EA s.n.* (PCCI). C, old fields/prairie plantings and recently disturbed open ground.

Erigeron philadelphicus L., common fleabane—*BSS 103* (ALBC, PCCI). O, same habitats as other *Erigeron* spp. but perhaps more often in moist and/or shaded areas.

Erigeron strigosus Willd., daisy fleabane—*JDS 4048* (ALBC, PCCI), *MV 23* (PCCI). C, old fields, prairie plantings, thickets, and borders.

Eupatorium perfoliatum L., boneset—*BSS 232* (ALBC, PCCI). C, sedge meadows, wet thickets, open swamps, and shores. †NW.

Eurybia macrophylla (L.) Cass., large-leaved aster—*BSS 2412*, *MW s.n.* (PCCI). O, mature upland forests and swamp borders. †SE1.

Euthamia graminifolia (L.) Nutt., grass-leaved goldenrod—*BSS 234*, *243* (ALBC, PCCI). F, old fields, clearings, thickets, borders, and open wetlands.

Eutrochium maculatum (L.) E. E. Lamont, joe-pye-weed—*BSS 228* (ALBC, PCCI), *446* (ALBC). A, widespread and abundant in sedge meadows, wet thickets, open swamps, and shores.

Helianthus decapetalus L., thin-leaved sunflower—*BSS 2442* (MICH, PCCI). LC, forest borders along firebreak W of "North Prairie," N of Cloverdale Road.

Helianthus giganteus L., tall sunflower—*BSS 230* (ALBC, PCCI). F, sedge meadows, wet thickets, and shores.

Helianthus hirsutus Raf., hairy sunflower—*BSS 2381* (PCCI), *2452* (MICH). LC, forest borders. **SPECIAL CONCERN.**

Helianthus strumosus L., pale-leaved sunflower—*BSS 273* (ALBC, PCCI). R, thickets.

Helianthus tuberosus L., Jerusalem-artichoke—*BSS 2542* (MICH, PCCI). R, along Cloverdale Road at bridge over Cedar Creek.

**Hieracium aurantiacum* L., orange hawkweed—*BSS 2160* (PCCI). O, old fields.

**Hieracium caespitosum* Dumort., king devil—*BSS 2084, 2104* (PCCI). C, old fields and other disturbed open areas. Apparent hybrids, presumably with *H. flagellare*, are also present (*BSS 2109*, PCCI).

**Hieracium flagellare* Willd., whip-lash hawkweed—*BSS 2106* (MICH, PCCI). R, old fields.

Hieracium gronovii L., hairy hawkweed—*BSS 2309* (PCCI). LC, sandy old field near terminus of Cedar Creek Trail, and rare and local in dry forests.

Hieracium longipilum L., prairie hawkweed—*BSS 2419* (PCCI). R, sandy old field near terminus of Cedar Creek Trail.

**Hypochaeris radicata* L., cat's-ear—*BSS 2105* (PCCI), *2159* (MICH). F, disturbed, often compacted open ground, such as near buildings, along trails, and in old fields and prairie plantings.

Krigia biflora (Walter) S. F. Blake, false dandelion—*BSS 2164* (MICH, PCCI). R, dry wooded banks above Cedar Creek.

Krigia virginica (L.) Willd., dwarf dandelion—*BSS 2082* (PCCI). LC, sandy old field near terminus of Cedar Creek Trail.

Lactuca biennis (Moench) Fernald, tall blue lettuce—*BSS 267* (ALBC, PCCI). O, wetland openings and borders.

Lactuca canadensis L., wild lettuce—*BSS 2312* (PCCI). O, old fields and borders.

**Lactuca serriola* L., prickly lettuce—*BSS 2404* (PCCI). R, waste area behind Hyla House.

**Leucanthemum vulgare* Lam., ox-eye daisy—*BSS 2110* (MICH, PCCI). C, old fields, thickets, and borders.

Packera aurea (L.) Á. Löve & D. Löve, golden ragwort—*BSS 14* (ALBC, PCCI), *RWP 689* (WMU). C, open swamps and wet thickets.

Prenanthes altissima L., tall white lettuce—*BSS 2468* (PCCI). C, upland forests, thickets, and swamps, flowering best at borders.

Prenanthes racemosa Michx., glaucous white lettuce—*BSS 257* (ALBC, PCCI). R, open tamarack swamp and wet thicket.

Pseudognaphalium obtusifolium (L.) Hilliard & B. L. Burtt, fragrant cudweed—*BSS 304* (ALBC, PCCI). F, old fields and dry thickets, on sandy soils.

Ratibida pinnata (Vent.) Barnhart, yellow coneflower—*BSS 2394* (PCCI). R, a few plants in unplanted old field near Meadow Lodge; frequent in prairie plantings. †HP, ME, MW, N, NE, NW, SE1, SE2, SW. [*MV 26*, PCCI].

Rudbeckia hirta L., black-eyed susan—*BSS 149* (ALBC, PCCI). F, old fields, clearings, thickets, borders, and open wetlands; also widely planted. †HP, LT, ME, MW, N, NE, SE1, SE2, SW.

Rudbeckia laciniata L., tall coneflower—*BSS 2416* (MICH, PCCI). O, open swamps, wet thickets. †WOOD.

Solidago altissima L., tall goldenrod—*BSS 229*, *258* (ALBC, PCCI). C, old fields, thickets, forest borders.

Solidago caesia L., bluestem goldenrod—*BSS 2473* (PCCI). F, upland forests and occasionally in swamps. †SE1.

Solidago gigantea Aiton, late goldenrod—*BSS 261* (ALBC, PCCI). F, open swamps, wet thickets, and borders of sedge meadows.

Solidago juncea Aiton, early goldenrod—*BSS 2423* (PCCI). LC, old fields and clearings. †LT, SE1.

Solidago nemoralis Aiton, gray goldenrod—*BSS 2475* (PCCI). LC, old fields and clearings.

Solidago patula Muhl., swamp goldenrod—*BSS 254* (ALBC, PCCI). C, swamp forests, wet thickets, sedge meadows, shores and springs.

Solidago rugosa Mill., rough-leaved goldenrod—*BSS 247* (ALBC, PCCI). C, widespread in all but the wettest and driest habitats.

Solidago uliginosa Nutt., bog goldenrod—*BSS 272* (ALBC, PCCI). LC, sedge meadows and shores.

**Sonchus arvensis* L. subsp. *uliginosus* (M. Bieb.) Nyman, field sow-thistle—*BSS 2333*, *2440* (PCCI). O, disturbed wetland borders.

Symphyotrichum cordifolium (L.) G. L. Nesom, heart-leaved aster—*BSS 289* (ALBC, PCCI). †WOOD. F, upland forests, thickets, and borders.

Symphyotrichum drummondii (Lindl.) G. L. Nesom, Drummond's aster—*BSS 2514, 2515, 2520, 2521, 2522* (PCCI). F, old fields and borders. **THREATENED.**

Symphyotrichum firmum (Nees) G. L. Nesom, smooth swamp aster—*BSS 275* (ALBC, PCCI), *2470* (PCCI). A, forming dense stands in wet meadows, wet thickets, open swamps, and shores.

Symphyotrichum lanceolatum (Willd.) G. L. Nesom var. *interior* (Wiegand) Semple & Chmiel, panicled aster—*BSS 253* (ALBC, PCCI), *2529* (MICH), *2540* (PCCI). F, moist old fields, borders, and open swamps.

Symphyotrichum lateriflorum (L.) Á. Löve & D. Löve, calico aster—*BSS 476*, *477* (ALBC); *BSS 2538* (PCCI). C, upland forests, thickets, swamps, and borders. †WOOD.

Symphyotrichum novae-angliae (L.) G. L. Nesom, New England aster—*BSS 277* (ALBC, PCCI), *2503* (PCCI). O, old fields and thickets. †HP, N, NW.

Symphyotrichum pilosum (Willd.) G. L. Nesom, frost aster—*BSS 276* (ALBC, PCCI). C, old fields, prairie plantings, borders, and disturbed open ground.

Symphyotrichum puniceum (L.) Á. Löve & D. Löve, swamp aster—*BSS 270* (ALBC, PCCI), *2464* (MICH, PCCI). F, open swamps, wet thickets, and shores. †POND, SE1, SE2.

Symphyotrichum urophyllum (DC.) G. L. Nesom, arrow-leaved aster—*BSS 2499* (PCCI). O, borders, much less frequent than *S. drummondii.* †HP.

**Taraxacum officinale* F. H. Wigg., common dandelion—*BSS 5*, *41* (ALBC, PCCI). C, disturbed open ground.

**Tragopogon dubius* Scop., goat's beard—*JDS 4043* (ALBC, PCCI). F, old fields, prairie plantings, disturbed dry ground.

Vernonia missurica Raf., Missouri ironweed—*BSS 2474* (PCCI). R, clearings and moist thickets.

**Xanthium strumarium* L., common cocklebur—*BSS 2471* (MICH, PCCI). R, margin of wet meadow along Cloverdale Road in tire tracks.

BALSAMINACEAE

Impatiens capensis Meerb., spotted touch-me-not—*BSS 218* (ALBC, PCCI). C, wetlands, upland forests.

Impatiens pallida Nutt., pale touch-me-not—*BSS 217*, *260* (ALBC, PCCI). O, oak forests and thickets.

BERBERIDACEAE

**Berberis thunbergii* DC., Japanese barberry—*BSS 312* (ALBC, PCCI). R, thickets and swamps.

Podophyllum peltatum L., may-apple—*BSS 95* (ALBC, PCCI). C, upland forests and thickets.

BETULACEAE

Betula alleghaniensis Britton, yellow birch—*BSS 130* (ALBC, PCCI), *GJP 1825* (WMU). F, swamp forests, occasionally in upland forests.

Carpinus caroliniana Walter, blue-beech—*BSS 94* (ALBC, PCCI), *GJP 1826* (WMU), *MV 16* (PCCI). C, swamp forests and wet thickets, also low areas and slopes in mesic and dry-mesic upland forests.

Corylus americana Walter, hazelnut—*BSS 2053* (PCCI). O, roadsides, thickets, wetland borders.

Ostrya virginiana (Mill.) K. Koch, ironwood—*BSS 294* (ALBC, PCCI), *EA s.n.* (PCCI). C, upland forests, swamp borders.

IGNONIACEAE

**Campsis radicans* (L.) Bureau, trumpet-creeper—*BSS 2320* (PCCI). LC, N side Cloverdale Road opposite main entrance.

BORAGINACEAE

Hackelia virginiana (L.) I. M. Johnst., beggar's lice—*JDS 4089* (ALBC, PCCI). O, upland forests, including young weedy stands, and along trails.

**Myosotis scorpioides* L., forget-me-not—*BSS 2166* (PCCI). LC, shores, particularly along Cedar Creek.

BRASSICACEAE

**Alliaria petiolata* (M. Bieb.) Cavara & Grande, garlic mustard—*BSS 2022*, *JS 13* (PCCI). F, shaded margins of Cloverdale Road, weedy young forests, and sporadic elsewhere.

**Arabidopsis thaliana* (L.) Heynh., mouse-ear cress—*BSS 46* (ALBC, PCCI). C, old fields, trails, roadsides, and elsewhere on disturbed open ground.

**Barbarea vulgaris* R. Br., yellow rocket—*BSS 335* (ALBC), *JS 9* (PCCI). F, disturbed open ground, mostly near main campus.

**Berteroa incana* (L.) DC., hoary alyssum—*BSS 2533* (PCCI). R, disturbed open ground.

Boechera canadensis (L.) Al-Shehbaz, sickle-pod—*BSS 2355* (PCCI). R, beech-maple forest.

**Capsella bursa-pastoris* (L.) Medik., shepherd's-purse—*BSS 2009* (MICH, PCCI). O, old fields and along trails.

Cardamine bulbosa (Muhl.) Britton, Sterns & Poggenb., spring cress—*BSS 2061* (PCCI), *JDS 4231* (ALBC), *RWP 692* (WMU). F, swamps, wet thickets, and seeps.

Cardamine concatenata (Michx.) O. Schwarz, cut-leaved toothwort—*BSS 2034* (PCCI). LC, wooded toeslopes adjacent to swamp forest.

Cardamine diphylla (Michx.) Alph. Wood, two-leaved toothwort—*BSS 337* (ALBC), *2085* (PCCI). LC, bases of forested slopes and margins of swamp forest.

Cardamine douglassii Britton, pink spring cress—*BSS 22*, *JDS 4022* (ALBC, PCCI). C, mature upland forests, swamp forests, and wet thickets.

**Cardamine hirsuta* L., hoary bitter cress—*BSS 2014* (MICH, PCCI). F, old fields and other disturbed open places.

Cardamine pensylvanica Willd., Pennsylvania bitter cress—*BSS 31*, *2070* (PCCI); *BSS 330* (ALBC). F, depressions in open swamps; seeps and spring runs.

Cardamine pratensis L., cuckoo-flower—*BSS 2074* (PCCI). O, springy open conifer swamps; more locally distributed and less common than *Cardamine pensylvanica*.

**Draba verna* L., whitlow-grass—*BSS 2008* (PCCI). LC, raw, disturbed soils, as near buildings and on trails.

**Hesperis matronalis* L., dame's rocket—*BSS 2136* (MICH, PCCI). R, thickets and forest borders.

**Lepidium campestre* (L.) R. Br., field cress—*JDS 4047* (ALBC, PCCI), *JS 6* (PCCI). O, old fields and disturbed dry open ground.

Lepidium virginicum L., common peppergrass—*BSS 2050*, *2245* (PCCI). F, old fields and disturbed open ground.

Nasturtium officinale W. T. Aiton, watercress—*BSS 2230* (PCCI). LC, springy feeder stream S of Brewster Lake ("Rattlesnake Creek").

**Sisymbrium altissimum* L., tumble mustard—*BSS 2151* (PCCI). R, bare soil near Prairie View building.

**Sisymbrium officinale* L., hedge mustard—*BSS 2231* (PCCI). R, raw, disturbed soils.

**Thlaspi arvense* L., penny cress—*BSS 2038b* (MICH, PCCI). R, raw, disturbed soils.

**Turritis glabra* L., tower mustard—*BSS 2012*, *JS 14* (PCCI). C, old fields and other disturbed open places.

CAMPANULACEAE

Campanula aparinoides Pursh var. *grandiflora* Holz., marsh bellflower—*BSS 184*, *201* (ALBC, PCCI). C, sedge meadows, shores, and wet thickets.

Campanulastrum americanum (L.) Small, tall bellflower—*BSS 206*, *JDS 4057* (ALBC, PCCI). F, upland forests (including weedy young stands), thickets, and borders. †HP, WOOD.

Lobelia inflata L., Indian-tobacco—*BSS 2525* (PCCI). R, two-track in oak forest E of Whitefish Lake. †WOOD.

Lobelia siphilitica L., great blue lobelia—*BSS 248* (ALBC, PCCI). F, open swamps, wet thickets, borders, and shores.

CANNABACEAE

Celtis occidentalis L., hackberry—*BSS 2135* (MICH, PCCI). O, mostly in weedy young forests.

CAPRIFOLIACEAE

**Lonicera ×bella* Zabel, hybrid honeysuckle—*BSS 2060* (MICH, PCCI). C, widespread in all but the wettest and most shaded habitats; apparently the most abundant non-native honeysuckle on the property.

Lonicera dioica L., red honeysuckle—*BSS 50* (ALBC, PCCI). O, sporadically distributed in a variety of habitats, usually as small, sterile individuals.

**Lonicera maackii* (Rupr.) Herder, Amur honeysuckle—*BSS 2111* (MICH, PCCI). R, mature shrubs widely scattered at forest borders.

**Lonicera morrowii* A. Gray, Morrow honeysuckle—*BSS 11* (ALBC, PCCI), *2078* (MICH, PCCI). F, in same habitats as *Lonicera tatarica* and *Lonicera ×bella*.

**Lonicera tatarica* L., Tartarian honeysuckle—*BSS 55* (ALBC, PCCI). O, roadsides, disturbed thickets.

Triosteum aurantiacum E. P. Bicknell, horse-gentian—*BSS 317* (ALBC, PCCI). O, thickets, borders of upland and swamp forests.

CARYOPHYLLACEAE

**Arenaria serpyllifolia* L., thyme-leaved sandwort—*BSS 2035* (MICH, PCCI), *JDS 4237* (ALBC). C, disturbed open ground, old fields, and prairie plantings.

**Cerastium fontanum* Baumg., mouse-ear chickweed—*BSS 17* (ALBC, PCCI), *363* (ALBC), *2128* (PCCI). C, disturbed open ground, old fields and prairie plantings, and along trails, where spreading locally to sedge meadows and wet thickets.

**Cerastium semidecandrum* L., small mouse-ear chickweed—*BSS 2037* (PCCI). C, same habitats as *Cerastium fontanum*.

**Dianthus armeria* L., Deptford pink—*BSS 140*, *JDS 4034* (ALBC, PCCI). C, old fields and disturbed open ground.

Silene antirrhina L., sleepy catchfly—*BSS 2152* (PCCI). R, disturbed open sandy ground.

**Silene latifolia* Poir., white campion—*BSS 2013*, *2107* (PCCI). C, old fields and disturbed open areas throughout.

**Silene noctiflora* L., night-flowering catchfly—*BSS 2153* (MICH, PCCI). R, old fields, plantings, and disturbed open areas near buildings.

**Silene vulgaris* (Moench) Garcke, bladder campion—*BSS 2172* (PCCI). R, old fields/prairie plantings.

**Stellaria graminea* L., starwort—*BSS 2272* (MICH, PCCI). LC, old field and thicket N of Cloverdale Road, opposite Research Lab.

Stellaria longifolia Willd., long-leaved chickweed—*BSS 76* (ALBC, PCCI), *362* (ALBC). O, open swamps, seeps, shores.

**Stellaria media* (L.) Vill., common chickweed—*BSS 2040* (MICH, PCCI), *2080* (PCCI); *JDS 4241* (ALBC). F, disturbed open ground.

CELASTRACEAE

**Celastrus orbiculatus* Thunb., oriental bittersweet—*BSS 2224* (MICH, PCCI). LC, weedy thicket S of Aurohn Lake, but not observed elsewhere.

Celastrus scandens L., climbing bittersweet—*BSS 2173* (MICH, PCCI), *MB s.n.* (PCCI). O, forest borders, gaps, and margins of wetlands, mostly as sterile stems. Widespread, unlike *Celastrus orbiculatus*.

**Euonymus alatus* (Thunb.) Siebold, winged euonymus—*BSS 2137* (MICH, PCCI). R, widely scattered and uncommon in upland forests and borders.

**Euonymus europaeus* L., spindle tree—*BSS 309* (ALBC, PCCI). R, Batts Cottage, perhaps only as a planting.

Euonymus obovatus Nutt., running strawberry-bush— *BSS 2079*, *MB s.n.* (PCCI); *JDS 4238* (ALBC). F, mature upland forests, swamp borders, and occasional in swamp interiors.

Parnassia glauca Raf., grass-of-parnassus—*BSS 269* (ALBC, PCCI). LC, shoreline fen, Brewster Lake (at least historically) and springy openings in conifer swamps.

CONVOLVULACEAE

Calystegia sepium (L.) R. Br., hedge bindweed—*BSS 2382* (PCCI). LC, waste area behind Hyla House.

Cuscuta gronovii Roem. & Schult., common dodder—*BSS 469* (MICH). O, wet thickets and open wetlands.

CORNACEAE

Cornus alternifolia L. f., alternate-leaved dogwood—*BSS 80* (ALBC, PCCI), *EA s.n.* (PCCI). O, moist upland forests and swamp borders.

Cornus amomum Mill., silky dogwood—*JDS 4076* (ALBC, PCCI). O, open swamps, wet thickets, sedge meadows, shores.

Cornus florida L., flowering dogwood—*BSS 92* (ALBC, PCCI); *EA s.n.*, *JS 7*, *MV 17* (PCCI). F, upland forests and borders.

Cornus foemina Mill. subsp. *racemosa* (Lam.) J. S. Wilson, gray dogwood—*BSS 287* (ALBC, PCCI), *EA s.n.* (PCCI). C, oak forests, thickets, borders; also important in wetlands, where it has encroached on open sedge meadow, particularly S of Cloverdale Road (see Slaughter & Skean 2003b).

Cornus sericea L., red-osier—*BSS 78* (ALBC, PCCI). C, open swamps, wet thickets, and shores.

DROSERACEAE

Drosera rotundifolia L., round-leaved sundew—*BSS 2274* (PCCI). R, springy open cedar-tamarack swamp.

ELAEAGNACEAE

**Elaeagnus umbellata* Thunb., autumn-olive—*BSS 60, 281* (ALBC, PCCI); *JS 10* (PCCI). A, throughout in all but the wettest habitats, increasing in swamps affected by insect- and beaver-induced tamarack and ash die-off.

ERICACEAE

Chamaedaphne calyculata (L.) Moench, leatherleaf—*BSS 2368* (PCCI). R, border of wooded bog, Whitefish Lake.

Chimaphila maculata (L.) Pursh, spotted wintergreen—*BSS 2311* (PCCI). R, wooded banks above Cedar Creek.

Gaultheria hispidula (L.) Bigelow, creeping-snowberry—*BSS 413* (MICH). R, hummocks in cedar swamp.

Gaylussacia baccata (Wangenh.) K. Koch, huckleberry—*BSS 2508* (PCCI). LC, wooded bog, Whitefish Lake.

Monotropa uniflora L., Indian-pipe—*BSS 2354* (PCCI). O, upland forests.

Pyrola elliptica Nutt., large-leaved shinleaf—*BSS 2249* (PCCI). R, oak forest above Cedar Creek.

Vaccinium corymbosum L., highbush blueberry—*BSS 126* (ALBC, PCCI). F, open swamps and shores.

Vaccinium oxycoccos L., small cranberry—*BSS 2279* (MICH, PCCI). R, springy open cedar-tamarack swamp on *Sphagnum*.

Vaccinium pallidum Aiton, hillside blueberry—*BSS 2062* (PCCI). R, dry banks in oak forests near Whitefish Lake and Cedar Creek.

EUPHORBIACEAE

Acalypha rhomboidea Raf., three-seeded mercury—*BSS 244* (ALBC, PCCI). O, disturbed open ground, berms.

Euphorbia maculata L., spotted spurge—*BSS 177* (ALBC, PCCI). F, waste areas, parking lots, and disturbed open ground generally.

Euphorbia nutans Lag., eyebane—*BSS 2531* (PCCI). R, recently disturbed open ground, such as at main entrance. Also noted formerly in sandy old field near terminus of Cedar Creek Trail (see Howell and Lucas 2018).

FABACEAE

Amphicarpaea bracteata (L.) Fernald, hog-peanut—*BSS 165*, *JDS 4054* (ALBC, PCCI). C, widespread in a variety of upland and wetland habitats.

Apios americana Medik., groundnut—*JDS 4055*, *4083* (ALBC, PCCI); *JL 201191701* (HCHM). C, sedge meadows, wet thickets, open swamps, and shores.

Desmodium cuspidatum (Willd.) Loud., smooth-bracted tick-trefoil—*BSS 2411* (MICH, PCCI). R, base of wooded bank above Cedar Creek at terminus of Cedar Creek Trail.

Desmodium glabellum (Michx.) DC., tick-trefoil—*BSS 458* (ALBC), *2424* (PCCI), *2448* (MICH); *JDS 4060* (ALBC, PCCI). F, old fields, thickets, and forest borders.

Desmodium obtusum (Willd.) DC., stiff tick-trefoil—*BSS 2421* (PCCI). R, sandy old field near terminus of Cedar Creek Trail.

Desmodium paniculatum (L.) DC., panicled tick-trefoil—*BSS 2415*, *2422*, *2425* (PCCI); *BSS 2418* (MICH). F, same habitats as *Desmodium glabellum* but more often in shaded areas.

Gleditsia triacanthos L., honey locust—*BSS 2519* (PCCI). R, one seedling noted along trail near Aurohn Lake, not native to site.

Hylodesmum glutinosum (Willd.) H. Ohashi & R. R. Mill, clustered-leaved tick-trefoil—*BSS 227* (ALBC, PCCI). F, rich upland forests. †WOOD.

Hylodesmum nudiflorum (L.) H. Ohashi & R. R. Mill, naked tick-trefoil—*BSS 2315* (PCCI). O, mature oak forests.

Lathyrus ochroleucus Hook., pale vetchling—*BSS 2087* (MICH, PCCI). LC, dry, semi-shaded bank above Cedar Creek.

Lathyrus palustris L., marsh pea—*BSS 188* (ALBC, PCCI). F, sedge meadows and shores.

**Lotus corniculatus* L., birdfoot trefoil—*BSS 2043* (MICH, PCCI). C, old fields, along trails, and elsewhere on disturbed open ground.

**Medicago lupulina* L., black medick—*BSS 246* (ALBC, PCCI). C, old fields and disturbed open ground generally.

**Medicago sativa* L., alfalfa—*BSS 2213* (PCCI). F, old fields and borders.

**Melilotus albus* Medik., white sweet-clover—*JDS 4049* (ALBC, PCCI). F, old fields, roadsides, and disturbed open ground.

**Melilotus officinalis* (L.) Pall., yellow sweet-clover—*BSS 2265* (PCCI). R, old fields and berms, main campus.

**Robinia pseudoacacia* L., black locust—*BSS 2134* (PCCI). O, forest borders, thickets, clearings.

**Securigera varia* (L.) Lassen, crown-vetch—*BSS 133* (ALBC, PCCI). LC, forming large sprawling patches along Cloverdale Road and locally elsewhere.

**Trifolium arvense* L., rabbitfoot clover—*BSS 2319* (MICH, PCCI). LC, old field/prairie planting behind Prairie View.

**Trifolium campestre* Schreb., low hop clover—*BSS 2225* (MICH, PCCI). O, old fields and disturbed open ground, rather local.

**Trifolium dubium* Sibth., little hop clover—*BSS 2036* (MICH, PCCI). O, disturbed open, compacted ground, where easily overlooked.

**Trifolium hybridum* L., alsike clover—*BSS 2318* (MICH, PCCI). F, old fields, trails, disturbed open ground.

**Trifolium incarnatum* L., crimson clover—*BSS 2044* (MICH, PCCI), *JS 11* (PCCI). O, margins of old fields/prairie plantings, where persisting (and perhaps locally spreading) from firebreak seedings.

**Trifolium pratense* L., red clover—*BSS 251* (ALBC, PCCI), *MV 22* (PCCI). C, old fields, trails, disturbed open ground.

**Trifolium repens* L., white clover—*BSS 157* (ALBC, PCCI), *2108* (PCCI). C, old fields, trails, disturbed open ground.

Vicia americana Willd., American vetch—*BSS 64* (ALBC, PCCI). R, wet thicket N of Cloverdale Road.

**Vicia tetrasperma* (L.) Schreb., sparrow vetch—*BSS 2101* (MICH, PCCI). LC, scattered small colonies at field borders.

**Vicia villosa* Roth, hairy vetch—*BSS 2102* (PCCI). F, old fields, prairie plantings, and borders.

FACEAE

Fagus grandifolia Ehrh., American beech—*BSS 290* (ALBC, PCCI). C, widespread throughout in upland forests; codominant on esker and copses S of Cloverdale Road.

Quercus alba L., white oak—*BSS 320* (ALBC, PCCI). C, dry-mesic forests, wooded banks above lakes and Cedar Creek.

Quercus bicolor Willd., swamp white oak—*BSS 307* (ALBC, PCCI). R, ridge N of Batts Cottage.

Quercus macrocarpa Michx., bur oak—*BSS 450* (ALBC), *2281* (PCCI). F, copses, wetland borders, swamp forests.

Quercus muehlenbergii Engelm., chinquapin oak—*BSS 319* (ALBC, PCCI). LC, successional forest along Brewster Lake Trail N of Batts Cottage.

Quercus palustris Münchh., pin oak—*BSS 2510* (PCCI). R, a few small trees in wooded bog, Whitefish Lake.

Quercus rubra L., red oak—*BSS 2537* (PCCI). C, widespread throughout in upland forests and thickets; locally dominant.

Quercus velutina Lam., black oak—*BSS 303*, *305*; *JDS 4039* (ALBC, PCCI). C, dry-mesic forests, borders, and clearings, especially on sandy soil.

GENTIANACEAE

Frasera caroliniensis Walter, American columbo—*BSS 2118* (PCCI). LC, one large colony in oak forest SW of campus and prairie plantings.

Gentiana andrewsii Griseb., bottle gentian—*BSS 2469* (PCCI). R, wet thickets and shaded sedgy ground.

GERANIACEAE

Geranium maculatum L., wild geranium—*BSS 56* (ALBC, PCCI), *JS 1* (PCCI). C, upland forests, thickets, and occasionally in tamarack swamps. †WOOD.

**Geranium pusillum* L., small geranium—*BSS 2190* (PCCI). R, disturbed open ground.

Geranium robertianum L., herb robert—*BSS 97* (ALBC, PCCI). O, beech-maple forest S of Cloverdale Road.

GROSSULARIACEAE

Ribes americanum Mill., wild black currant—*BSS 2021* (PCCI). O, sedge meadows, wet thickets, and shores.

Ribes cynosbati L., wild gooseberry—*BSS 2030* (PCCI). C, forests and borders, often weedy.

Ribes hirtellum Michx., swamp gooseberry—*BSS 51* (ALBC, PCCI). O, wet meadows, shores, and springy areas in open swamps.

HALORAGACEAE

Myriophyllum sibiricum Komarov, spiked water-milfoil—*BSS 2342* (PCCI), *2492* (MICH). LC, Brewster Lake.

HAMAMELIDACEAE

Hamamelis virginiana L., witch-hazel—*BSS 96* (ALBC, PCCI), *MV 12* (PCCI). F, upland, especially oak-dominated, forests.

HYPERICACEAE

**Hypericum perforatum* L., common St. John’s-wort—*BSS 459* (ALBC). C, old fields and disturbed open ground.

Hypericum punctatum Lam., spotted St. John’s-wort—*BSS 460* (ALBC). O, wet thickets and swamp borders.

Triadenum virginicum (L.) Raf., marsh St. John's-wort—*BSS 2511* (PCCI). LC, wooded bog, Whitefish Lake.

JUGLANDACEAE

Carya cordiformis (Wang.) K. Koch, bitternut hickory—*BSS 322* (ALBC, PCCI). F, mesic and dry-mesic forests and borders.

Carya glabra (Mill.) Sweet, pignut hickory—*BSS 2064* (PCCI). F, dry-mesic forests and borders.

Carya ovata (Mill.) K. Koch, shagbark hickory—*BSS 71*, *308* (ALBC, PCCI). O, dry-mesic to mesic forests and borders.

Juglans cinerea L., butternut—*BSS 302* (ALBC, PCCI). R, sandy ridge N of Batts Cottage.

Juglans nigra L., black walnut—*BSS 467* (ALBC). C, widespread and especially prevalent in young, weedy forests, borders, thickets, and establishing in old fields.

LAMIACEAE

Agastache nepetoides (L.) Kuntze, yellow giant hyssop—*BSS 2441* (PCCI). O, mature oak forests and borders on NW part of the property. †WOOD.

Blephilia hirsuta (Pursh) Benth., wood mint—*BSS 408* (MICH). LC, wet thickets S of Cloverdale Road.

Clinopodium vulgare L., wild-basil—*BSS 2259* (PCCI). O, old fields and borders, especially on sandy soils.

Collinsonia canadensis L., stoneroot—*BSS 2444* (MICH, PCCI). F, mature upland forests and swamp borders.

**Glechoma hederacea* L., ground-ivy—*BSS 336* (ALBC). LC, wet thicket near entrance to Beech Maple Ridge Trail.

**Lamium amplexicaule* L., henbit—*BSS 2011* (MICH, PCCI). R, trails and in plantings/flowerbeds.

**Lamium purpureum* L., purple dead-nettle—*BSS 18* (ALBC, PCCI), *JS 12* (PCCI). F, old fields and raw open ground, especially on and near main campus.

**Leonurus cardiaca* L., motherwort—*BSS 156* (ALBC, PCCI). O, old fields and waste areas.

Lycopus americanus Muhl., common water horehound—*BSS 223* (ALBC, PCCI). O, sedge meadows.

Lycopus rubellus Moench, stalked water horehound—*BSS 2447* (MICH, PCCI). O, quaking muck in buttonbush depressions.

Lycopus uniflorus Michx., northern bugle weed—*BSS 437*, *464* (ALBC). C, widespread in open to partially shaded wetlands.

Mentha canadensis L., wild mint—*BSS 221* (ALBC, PCCI), *461* (ALBC). C, sedge meadows, seeps, and shores, sometimes in more shaded situations.

Monarda fistulosa L., wild-bergamot—*BSS 148* (ALBC, PCCI). F, old fields, thickets, and forest borders. †HP, ME, MW, N, NE, NW, SE1, SE2, SW. [*MV 21*, PCCI].

**Nepeta cataria* L., catnip—*BSS 2351* (PCCI). R, disturbed open ground along Brewster Lake Trail N of Cloverdale Road.

Prunella vulgaris L., self-heal—*BSS 162* (ALBC, PCCI), *462* (ALBC); *MW s.n.* (PCCI). F, widespread on and along trails and in a variety of ± shaded upland and wetland habitats.

Scutellaria galericulata L., marsh skullcap—*BSS 2256* (PCCI). O, sedge meadows and shores.

Scutellaria lateriflora L., mad-dog skullcap—*BSS 451* (ALBC). F, swamps, wet thickets, and shores.

LENTIBULARIACEAE

Utricularia gibba L., humped bladderwort—*BSS 2377*, *2518* (PCCI). LC, shore and floating sedge peat mats, Aurohn Lake.

Utricularia vulgaris L., common bladderwort—*BSS 122* (ALBC, PCCI). C, lakes and drainages, the stems and foliage forming large, noticeable masses.

LIMNANTHACEAE

Floerkea proserpinacoides Willd., false mermaid—*BSS 35* (ALBC, PCCI). C, upland forests.

LYTHRACEAE

Decodon verticillatus (L.) Elliott, whorled loosestrife—*JDS 4070* (ALBC, PCCI). F, shores, springy areas, and on loose, unstable mucks.

**Lythrum salicaria* L., purple loosestrife—*BSS 154* (ALBC, PCCI). A, open wetlands (especially marshes along Cedar Creek), roadsides, and disturbed moist ground generally. Remains abundant despite releases of the biological control agent *Galerucella calmariensis* in 2001, 2003, 2006, and 2013 (Howell and Lucas 2018).

MALVACEAE

**Abutilon theophrasti* Medik., velvet-leaf—*BSS 2332* (PCCI), *2501* (MICH). O, open disturbed ground, waste areas, and plantings.

**Malva neglecta* Wallr., common mallow—*BSS 2385* (PCCI). R, disturbed, compacted open ground.

Tilia americana L., basswood—*BSS 295* (ALBC, PCCI). C, upland forests; frequent in swamps.

MENISPERMACEAE

Menispermum canadense L., moonseed—*JDS 4242* (ALBC). F, borders and thickets, uplands and wetlands.

MENYANTHACEAE

Menyanthes trifoliata L., buckbean—*BSS 127* (ALBC, PCCI). LC, springy areas on shore of Brewster Lake (at least formerly) and cedar-tamarack swamps.

MOLLUGINACEAE

**Mollugo verticillata* L., carpetweed—*BSS 2260* (MICH, PCCI). O, parking lots, sidewalks, and disturbed, compacted open ground.

MONTIACEAE

Claytonia virginica L., spring-beauty—*BSS 29*, *JDS 4028* (ALBC, PCCI). C, mature upland forests. †WOOD.

MORACEAE

**Morus alba* L., white mulberry—*BSS 2122* (PCCI). F, forest borders, thickets, and seeding into old fields and waste areas.

MYRSINACEAE

Lysimachia ciliata L., fringed loosestrife—*BSS 151* (ALBC, PCCI). O, swamp borders and wet thickets.

Lysimachia lanceolata Walter, lance-leaved loosestrife—*BSS 434* (ALBC). R, wet thickets and wooded banks above Cedar Creek.

Lysimachia quadriflora Sims, prairie loosestrife—*BSS 2338* (MICH, PCCI). R, a few individuals in shore fen, E side Brewster Lake.

Lysimachia thyrsiflora L., tufted loosestrife—*BSS 107* (ALBC, PCCI), *GJP 1824* (WMU). F, wet meadows, marshes, and shores.

Trientalis borealis Raf., star-flower—*BSS 98* (ALBC, PCCI). F, swamp forests, mostly S of Cloverdale Road.

NYSSACEAE

Nyssa sylvatica Marshall, black-gum—*BSS 2200* (PCCI). R, margins of small, inundated kettle depressions.

OLEACEAE

Fraxinus americana L., white ash—*BSS 2539* (PCCI). A, upland forests, thickets, and wetland margins, mostly as seedlings and saplings. Many individuals producing fruit.

Fraxinus nigra Marshall, black ash—*BSS 70*, *300* (ALBC, PCCI); *BSS 409*, *411*, *468* (ALBC). O, swamp forests, formerly important but much reduced by emerald ash borer. See Slaughter and Skean (2003b).

Fraxinus pennsylvanica Marshall, green ash—*BSS 2207* (MICH, PCCI). O, wet swamps and borders.

**Syringa vulgaris* L., common lilac—*BSS 6* (ALBC, PCCI). R, roadsides, perhaps only represented by planted individuals, though the species has a propensity to spread locally.

ONAGRACEAE

Circaea alpina L., small enchanter's-nightshade—*BSS 378*, *422* (ALBC); *BSS 640* (MICH). F, swamp forests.

Circaea canadensis (L.) Hill, enchanter's-nightshade—*BSS 203*, *207* (ALBC, PCCI); *EA s.n.* (PCCI). A, ubiquitous in shaded upland habitats, especially young, weedy forests and thickets.

Epilobium coloratum Biehler, cinnamon willow-herb—*BSS 256* (ALBC, PCCI). F, swamps, wet thickets, sedge meadows, shores, exposed soils in seasonally inundated areas.

**Epilobium hirsutum* L., great hairy willow-herb—*BSS 194* (ALBC, PCCI). LC, beaver-impounded drainage S of Brewster Lake and Cloverdale Road.

Epilobium leptophyllum Raf., fen willow-herb—*JDS 4074* (ALBC, PCCI). R, Brewster Lake shoreline.

Epilobium strictum Spreng., downy willow-herb—*JDS 4077* (ALBC, PCCI). R, Brewster Lake shoreline.

Ludwigia palustris (L.) Elliott, water-purslane—*BSS 2378* (PCCI). O, shores and exposed wet ground.

Oenothera biennis L., common evening-primrose—*BSS 2393* (PCCI). O, old fields and borders; introduced to several prairie plantings. †HP, ME, MW, N, NW, SE1, SW.

Oenothera clelandii W. Dietr., P. H. Raven & W. L. Wagner, evening-primrose—*BSS 2420* (PCCI). R, sandy old field near terminus of Cedar Creek Trail.

OROBANCHACEAE

Agalinis purpurea (L.) Pennell, purple false foxglove—*BSS 263* (ALBC, PCCI). LC, shores.

Aureolaria flava (L.) Farw., smooth false foxglove—*BSS 2446* (PCCI). R, one small patch on wooded bank above Whitefish Lake.

Conopholis americana (L.) Wallr., squaw-root—*JDS 4090* (ALBC, PCCI). F, upland forests, especially oak stands.

Epifagus virginiana (L.) Bart., beech-drops—*BSS 291* (ALBC, PCCI). C, prevalent in beech-maple forests and frequent in drier forests where beech is present.

Pedicularis canadensis L., wood-betony—*BSS 48* (ALBC, PCCI), *MV 13* (PCCI). LC, bases of slopes in beech-maple forest.

Pedicularis lanceolata Michx., swamp-betony—*BSS 250* (ALBC, PCCI). F, springy areas in open swamps, wet thickets, sedge meadows, and shores.

OXALIDACEAE

**Oxalis dillenii* Jacq., common yellow wood-sorrel—*BSS 2203* (PCCI). O, old fields and prairie plantings.

Oxalis stricta L., yellow wood-sorrel—*BSS 145* (ALBC, PCCI). O, disturbed open ground.

PAPAVERACEAE

Dicentra cucullaria (L.) Bernh., dutchman's-breeches—*JDS 4020* (ALBC, PCCI). R, moist thicket S of Cloverdale Road. †WOOD.

Sanguinaria canadensis L., bloodroot—*JDS 4026* (ALBC, PCCI). O, upland forests and thickets. †WOOD.

PARNASSIACEAE – see CELASTRACEAE

PHRYMACEAE

Mimulus ringens L., monkey-flower—*BSS 222* (ALBC, PCCI). O, shores and seasonally inundated wet open ground.

Phryma leptostachya L., lopseed—*BSS 205*, *JDS 4088* (ALBC, PCCI); *EA s.n.* (PCCI). O, upland forests, mostly mature stands.

PHYTOLACCACEAE

Phytolacca americana L., pokeweed—*BSS 2326* (PCCI). F, waste areas, old fields, thickets, and borders.

PLANTAGINACEAE

Chelone glabra L., turtlehead—*BSS 249* (ALBC, PCCI). F, open swamps, wet thickets, sedge meadows, and shores.

Nuttallanthus canadensis (L.) D. A. Sutton, blue toadflax—*BSS 2083* (PCCI). LC, sandy old field near terminus of Cedar Creek Trail.

**Plantago lanceolata* L., narrow-leaved plantain—*BSS 134* (ALBC, PCCI), *JF s.n.* (PCCI). A, old fields, disturbed open ground generally, and along trails in shaded habitats.

Plantago rugelii Decne., Rugel's plantain—*BSS 176* (ALBC, PCCI). C, same habitats as *Plantago lanceolata*, but less prevalent away from trails and frequently disturbed ground.

**Plantago virginica* L., dwarf plantain—*BSS 2189* (MICH, PCCI). R, gravel parking area, Research Lab.

**Veronica arvensis* L., field speedwell—*BSS 47* (ALBC, PCCI). F, raw open ground, old fields, prairie plantings, and berms.

**Veronica officinalis* L., common speedwell—*BSS 2163* (PCCI). F, compacted soils on and along shaded trails, sporadic elsewhere in forests.

**Veronica persica* Poir., bird's-eye speedwell—*BSS 2568* (MICH, PCCI). R, compacted soils and pavement cracks, main campus.

**Veronica serpyllifolia* L., thyme-leaved speedwell—*BSS 339* (MICH), *2051* (PCCI). F, old fields, trails, and occasionally elsewhere in a variety of habitats.

**Veronica verna* L., spring corn speedwell—*BSS 2038a* (MICH, PCCI). R, disturbed, open sandy ground, main campus. Easily overlooked.

POLEMCONIACEAE

Phlox divaricata L., wild blue phlox—*BSS 21* (ALBC, PCCI), *361* (ALBC). F, forming large colonies in mature beech-maple forest S of Cloverdale Road. †WOOD.

**Phlox paniculata* L., perennial phlox—*BSS 473* (ALBC). R, persisting from planting near entrance to Beech Maple Ridge Trail.

POLYGONACEAE

**Fallopia convolvulus* (L.) Á. Löve, black-bindweed—*BSS 2387* (PCCI). LC, waste area behind Hyla House.

Fallopia scandens (L.) Holub, false buckwheat—*BSS 2504* (PCCI). R, thicket near NE arm of Whitefish Lake.

Persicaria amphibia (L.) Delabare var. *emersa* (Michx.) J. C. Hickman, water smartweed—*BSS 2512* (PCCI). O, shores.

Persicaria amphibia (L.) Delabare var. *stipulacea* (N. Coleman) H. Hara, water smartweed—*BSS 2379* (PCCI). O, sedge meadows, spring runs, and shores.

Persicaria arifolia (L.) Haraldson, tear-thumb—*BSS 428* (MICH). O, locally prevalent in open swamp forests near Cedar Creek.

Persicaria hydropiper (L.) Delabare, water-pepper—*BSS 2505* (PCCI). O, exposed marsh bottoms and disturbed wet open ground.

Persicaria hydropiperoides (Michx.) Small, mild water-pepper—*BSS 2362* (PCCI), *2405* (MICH, PCCI). F, shores, often in standing water.

Persicaria lapathifolia (L.) Delabare, willow-weed—*BSS 2430* (PCCI). R, disturbed open ground behind Prairie View.

**Persicaria maculosa* Gray, lady's-thumb—*BSS 245*, *252* (ALBC, PCCI). O, disturbed moist ground.

Persicaria punctata (Elliott) Small, smartweed—*BSS 193* (ALBC, PCCI), *2467* (PCCI). F, springs, seeps, and mucky hollows, often in shallow water.

Persicaria sagittata (L.) H. Gross, arrow-leaved tear-thumb—*BSS 457* (ALBC), *JDS 4056* (ALBC, PCCI). F, open wetlands and shores.

Persicaria virginiana (L.) Gaertn., jumpseed—*BSS 209*, *JDS 4058* (ALBC, PCCI); *BSS 423* (ALBC); *EA s.n.* (PCCI). A, wooded habitats throughout, particularly abundant in young, weedy forests. †WOOD.

**Polygonum aviculare* L., knotweed—*BSS 2328* (MICH, PCCI). F, roads and trails and elsewhere on open, compacted ground.

**Rumex acetosella* L., sheep sorrel—*BSS 2015* (PCCI). C, old fields and other disturbed open places.

**Rumex crispus* L., curly dock—*BSS 142* (ALBC, PCCI). F, old fields, disturbed open ground.

**Rumex obtusifolius* L., bitter dock—*BSS 143* (ALBC, PCCI). O, disturbed moist ground.

Rumex orbiculatus A. Gray, great water dock—*BSS 274* (ALBC, PCCI). F, shores, drainages, and springs.

PORTULACACEAE

Portulaca oleracea L., purslane—*BSS 2261* (MICH, PCCI), *2390* (MICH). O, parking lots, sidewalks, and compacted open ground generally.

RANUNCULACEAE

Actaea pachypoda Elliott, white baneberry—*BSS 208* (ALBC, PCCI), *JS 13* (PCCI). O, mature upland forests.

Actaea rubra (Aiton) Willd., red baneberry—*BSS 2322* (PCCI). R, thinly scattered in swamp forests. †WOOD.

Anemone quinquefolia L., wood anemone—*BSS 2029* (PCCI). O, wooded toeslopes adjacent to swamp forest.

Anemone virginiana L., thimbleweed—*BSS 147* (ALBC, PCCI). O, young forests, borders, and thickets. †LT, WOOD.

Aquilegia canadensis L., wild columbine—*BSS 82* (ALBC, PCCI). †WOOD. O, swamp borders, wet thickets, and occasional in uplands.

Caltha palustris L., marsh-marigold— *BSS 15*, *JDS 4029* (ALBC, PCCI); *RWP 690* (WMU). C, swamps, wet thickets, sedge meadows, seeps, and shores.

Clematis virginiana L., virgin's bower—*BSS 182* (ALBC, PCCI). F, forest borders, open swamps, and thickets.

Coptis trifolia (L.) Salisb., goldthread—*BSS 38* (ALBC, PCCI). F, swamp forests, especially cedar stands.

Hepatica americana (DC.) Ker Gawl.—*BSS 23*, *JDS 4024* (ALBC, PCCI). F, mature upland forests.

Ranunculus abortivus L., small-flowered buttercup—*BSS 16*, *39* (ALBC, PCCI). C, widespread in wet to dry wooded habitats, including disturbed areas.

Ranunculus hispidus Michx. var. *caricetorum* (Greene) T. Duncan, swamp buttercup— *BSS 44* (ALBC, PCCI); *BSS 358*, *394* (ALBC); *JLL* 125 (BALT); *RWP 696* (WMU). F, swamps and wet thickets.

Ranunculus pensylvanicus L. f., bristly crowfoot—*BSS 2407* (PCCI). R, margins of dried marsh bottom E of Hyla House, S of Cloverdale Road.

Ranunculus recurvatus Poir., hooked crowfoot—*BSS 37* (ALBC, PCCI), *345* (ALBC). F, similar habitats as *Ranunculus abortivus*.

Thalictrum dasycarpum Fisch. & Avé-Lall., purple meadow-rue—*BSS 152* (ALBC, PCCI). F, open swamps, wet thickets, sedge meadows, and shores.

Thalictrum dioicum L., early meadow-rue—*BSS 27* (ALBC, PCCI). O, mature upland forests and wooded copses. †WOOD.

Thalictrum thalictroides (L.) Eames & B. Boivin, rue-anemone—*JDS 4025* (ALBC, PCCI). C, mature oak and beech-maple forests.

RHAMNACEAE

**Frangula alnus* Mill., glossy buckthorn—*BSS 2017* (PCCI). R, disturbed wet thickets and open tamarack swamps near Cloverdale Road; old fields.

Rhamnus alnifolia L'Her., alder-leaved buckthorn—*BSS 73* (ALBC, PCCI), *RWP 699* (WMU). O, open swamps, wet thickets, and shores, often in ecotones.

**Rhamnus cathartica* L., common buckthorn—*BSS 2271* (MICH, PCCI). R, one large, multi-trunked tree along Cloverdale Road across from Research Lab; saplings rare in weedy thicket near two-track along NE arm of Whitefish Lake.

ROSACEAE

Agrimonia gryposepala Wallr., tall agrimony—*BSS 150*, *226* (ALBC, PCCI). C, widespread in all but the wettest habitats, especially prevalent in disturbed thickets and young forests.

Agrimonia pubescens Wallr., soft agrimony—*BSS 430* (ALBC), *2414* (PCCI). F, upland forests (including young stands), borders, and thickets, but generally less common than *A. gryposepala*.

Amelanchier arborea (F. Michx.) Fernald, juneberry—*BSS 2089* (PCCI). R, wooded bank above Cedar Creek.

Amelanchier laevis Wiegand, smooth shadbush—*BSS 2566* (PCCI). R, sandy old field near terminus of Cedar Creek Trail.

Amelanchier spicata (Lam.) K. Koch, shadbush serviceberry—*BSS 72* (ALBC, PCCI). R, wet thicket N of Cloverdale Road.

Aronia prunifolia (Marshall) Rehder, chokeberry—*BSS 2367* (PCCI). R, wooded bog, Whitefish Lake.

Comarum palustre L., marsh cinquefoil—*BSS 2364* (PCCI). R, lagg adjacent to shrub swamp, Whitefish Lake.

Crataegus compacta Sarg., hawthorn—*BSS 2047* (MICH, PCCI). O, thickets and young forests S of Cloverdale Road.

Crataegus pruinosa (H. L. Wendl.) K. Koch, hawthorn—*BSS 2090* (PCCI). O, thickets and young forests S of Cloverdale Road.

Crataegus punctata Jacq., dotted hawthorn—*BSS 53* (ALBC, PCCI), *2048* (PCCI). F, old fields, thickets, and young forests.

Dasiphora fruticosa (L.) Rydb., shrubby cinquefoil—*JDS 4079* (ALBC, PCCI). O, localized populations along Brewster Lake (where augmented) and fen-like sedge meadow N of Cloverdale Road. †BL.

Fragaria virginiana Mill., wild strawberry—*BSS 10* (ALBC, PCCI). F, widespread in old fields, clearings, thickets, along trails; also in less disturbed habitats.

Geum canadense Jacq., white avens—*BSS 155* (ALBC, PCCI); *BSS 2410*, *EA s.n.*, *EA s.n.* (PCCI). A, widespread, especially abundant in young, weedy forests and thickets.

Geum laciniatum Murray, rough avens—*BSS 2252* (PCCI), *2436* (MICH). R, wet meadows.

Geum rivale L., purple avens—*BSS 129* (ALBC, PCCI). F, open swamp forests and seeps.

Geum vernum (Raf.) T. & G., spring avens—*BSS 2055* (MICH, PCCI). LC, moist young forest and thickets S of Aurohn Lake.

Malus coronaria (L.) Mill., American crab—*BSS 2046* (PCCI). O, thickets and young, weedy forests.

**Malus pumila* Mill., apple—*BSS 19* (ALBC, PCCI). O, old fields, thickets, and young, weedy forests, where persisting and locally establishing from old plantings.

**Potentilla argentea* L., silvery cinquefoil—*JDS 4052* (ALBC, PCCI). F, dry, compacted open ground, especially on trails and on and near main campus.

Potentilla norvegica L., rough cinquefoil—*BSS 2263* (PCCI). R, disturbed open ground, especially near structures.

**Potentilla recta* L., rough-fruited cinquefoil—*BSS 61*, *139*, *204b* (ALBC, PCCI). C, old fields and disturbed open ground.

Potentilla simplex Michx., old-field cinquefoil—*BSS 2536* (PCCI). C, old fields, clearings, thickets, forests and borders.

Prunus americana Marshall, American wild plum—*BSS 20* (ALBC, PCCI). O, sedge meadows and wet thickets.

**Prunus avium* (L.) L., sweet cherry—*BSS 2059* (MICH, PCCI). R, weedy young forest S of Aurohn Lake.

Prunus serotina Ehrh., wild black cherry—*BSS 283* (ALBC, PCCI); *MV 4, 6* (PCCI). C, forests (especially young stands), borders, thickets, clearings, and old fields.

Prunus virginiana L., choke cherry—*BSS 54* (ALBC, PCCI). F, upland forests and thickets, especially borders.

**Pyrus calleryana* Decne., callery pear—*BSW 1086* (MICH). R, Cloverdale Road.

Rosa carolina L., pasture rose—*BSS 2250* (PCCI). LC, wooded banks at terminus of Cedar Creek Trail.

**Rosa multiflora* Murray, multiflora rose—*BSS 131* (ALBC, PCCI). A, widespread in most habitats, forming noxious stands in young forests, thickets, and open swamps especially. Likely the most problematic invasive plant in natural communities at PCCI.

Rosa palustris Marshall, swamp rose—*BSS 197* (ALBC, PCCI). F, shores, buttonbush depressions, and marshy ground.

Rubus allegheniensis Porter, common blackberry—*BSS 102* (ALBC, PCCI). A, young forests, thickets, and old fields, especially borders.

Rubus flagellaris Willd., northern dewberry—*BSS 2100*, *2114*, *2204* (PCCI). F, old fields, borders, clearings, and occasionally wetlands.

Rubus occidentalis L., black raspberry—*BSS 159* (ALBC, PCCI). C, young forests, thickets, and old fields, especially borders.

Rubus pensilvanicus Poir., dewberry—*BSS 2113* (MICH, PCCI). O, young forests, thickets, and borders.

Rubus pubescens Raf., dwarf raspberry— *BSS 77* (ALBC, PCCI); *BSS 332*, *350* (ALBC); *RWP 698* (WMU). C, swamp forests and wet thickets.

Rubus strigosus Michx., wild red raspberry—*BSS 202* (ALBC, PCCI). F, young forests, thickets, and old fields, especially borders.

Spiraea alba Du Roi, meadowsweet—*BSS 2375* (PCCI). O, wet thickets and shores.

Spiraea tomentosa L., hardhack—*BSS 2513* (PCCI). R, lagg and margins of wooded bog, Whitefish Lake.

RUBIACEAE

Cephalanthus occidentalis L., buttonbush—*BSS 2358* (PCCI). F, shores, kettle depressions, and other ± open wetlands.

**Galium album* Mill., white bedstraw—*BSS 2570* (MICH, PCCI). R, Cloverdale Road opposite Research Lab.

Galium aparine L., cleavers—*BSS 30* (ALBC, PCCI), *440* (ALBC). C, moist forests, especially young, weedy stands; thickets and trails.

Galium asprellum Michx., rough bedstraw—*BSS 185*, *192* (ALBC, PCCI). C, sedge meadows, wet thickets, open swamps, and shores.

Galium boreale L., northern bedstraw—*BSS 2146* (PCCI). F, upland and swamp forests, sedge meadows, and shores.

Galium circaezans Michx., white wild licorice—*BSS 321* (ALBC, PCCI). C, upland forests.

Galium concinnum Torr. & A. Gray, shining bedstraw—*BSS 2247* (PCCI). F, rich beech-maple and oak forests, especially on banks.

Galium labradoricum (Wiegand) Wiegand, bog bedstraw—*BSS 117* (ALBC, PCCI). R, shore fen along Brewster Lake.

Galium lanceolatum Torr., yellow wild licorice—*BSS 2193* (PCCI). O, mature oak forest.

Galium pilosum Aiton, hairy bedstraw—*BSS 2303* (PCCI). O, sandy old field and adjacent oak forests.

Galium tinctorium L., stiff bedstraw—*BSS 2073* (PCCI). F, open wetlands on shores and along spring runs and streams.

Galium trifidum L., small bedstraw—*BSS 2335* (MICH, PCCI). O, shores.

Galium triflorum Michx., fragrant bedstraw—*BSS 43* (ALBC, PCCI), *2196* (PCCI). C, upland and lowland forests.

Mitchella repens L., partridge-berry—*BSS 292* (ALBC, PCCI), *EA s.n.* (PCCI). F, mature upland forests, swamp borders, hummocks within swamps.

RUTACEAE

Zanthoxylum americanum Mill., prickly-ash—*BSS 7*, *288* (ALBC, PCCI); *MB s.n.* (PCCI). F, thickets, wetland borders, open swamps.

SALICACEAE

Populus deltoides Marshall, cottonwood—*BSS 280* (ALBC, PCCI). O, moist open ground, mostly near Cedar Creek.

Populus grandidentata Michx., big-tooth aspen—*BSS 91* (ALBC, PCCI). F, upland forests, thickets, clearings, and borders.

Populus ×jackii Sarg., balm-of-Gilead—*JDS 4068* (ALBC, PCCI). LC, N side Cloverdale Road.

Populus tremuloides Michx., quaking aspen—*BSS 2028* (PCCI). O, old fields, thickets, young forests.

Salix amygdaloides Andersson, peach-leaved willow—*BSS 2187* (MICH, PCCI). F, wet meadows and thickets, especially along and near Cedar Creek.

Salix bebbiana Sarg., Bebb's willow—*BSS 49*, *284* (ALBC, PCCI). O, sedge meadows, wet thickets, and open swamps.

Salix candida Willd., hoary willow—*BSS 2179* (PCCI). R, springy open cedar-tamarack swamp.

Salix discolor Muhl., pussy willow—*BSS 52*, *93* (ALBC, PCCI); *BSS 481* (ALBC). F, shores, marshes, sedge meadows.

Salix eriocephala Michx., willow—*BSS 2168* (PCCI). O, shores and open wetlands along Cedar Creek.

Salix exigua Nutt., sandbar willow—*BSS 68* (ALBC, PCCI). F, open wetlands along Cedar Creek.

Salix nigra Marshall, black willow—*BSS 2408* (PCCI). O, marsh borders and shores.

Salix petiolaris Sm., slender willow—*BSS 2176* (PCCI). R, sedge meadows and swamp borders.

SANTALACEAE

Comandra umbellata (L.) Nutt., bastard-toadflax—*BSS 2229* (PCCI). R, fen-like sedge meadow N of Cloverdale Road.

SAPINDACEAE

Acer negundo L., box-elder—*BSS 8* (ALBC, PCCI). C, forest borders, weedy young forests, thickets, and disturbed areas.

Acer nigrum F. Michx., black maple—*BSS 463* (MICH). O, open swamp forests.

Acer rubrum L., red maple—*BSS 34, 296* (ALBC, PCCI); *MV 14* (PCCI). C, widespread in wetland and upland habitats, particularly swamps, shores, and oak-dominated forests on ± sandy soils.

Acer saccharinum L., silver maple—*BSS 310* (ALBC, PCCI), *2208* (PCCI). Originally collected from planted specimen; as a naturally occurring species, LC in wet swamps.

Acer saccharum Marshall, sugar maple—*BSS 301* (ALBC, PCCI). C, widespread throughout in upland forests; codominant on esker and copses S of Cloverdale Road.

SARRACENIACEAE

Sarracenia purpurea L., pitcher-plant—*BSS 2180* (PCCI). LC, springy open cedar-tamarack swamp; wooded bog, Whitefish Lake.

SAXIFRAGACEAE

Micranthes pensylvanica (L.) Haw., swamp saxifrage—*BSS 74* (ALBC, PCCI). O, swamps, wet thickets, seeps, and shores.

Mitella diphylla L., bishop's-cap—*BSS 42* (ALBC, PCCI). F, swamps and moist upland forests, especially ecotones at bases of slopes.

Mitella nuda L., naked miterwort—*BSS 40* (ALBC, PCCI). F, swamp forests.

SCROPHULARIACEAE

**Verbascum thapsus* L., mullein—*BSS 215*, *JDS 4042* (ALBC, PCCI). C, old fields, prairie plantings, and disturbed open ground generally.

SOLANACEAE

Physalis heterophylla Nees, clammy ground-cherry—*BSS 2191* (PCCI). O, disturbed open ground in old fields and near buildings.

Physalis longifolia Nutt., long-leaved ground-cherry—*BSS 2264* (MICH, PCCI). R, weedy berm near Visitor Center.

**Solanum carolinense* L., horse-nettle—*BSS 2242* (PCCI). C, old fields, prairie plantings, waste areas.

**Solanum dulcamara* L., bittersweet nightshade—*BSS 2348* (PCCI). F, open swamps, shores, disturbed areas.

Solanum ptychanthum Dunal, black nightshade—*BSS 2383* (MICH, PCCI). O, waste areas, disturbed open ground.

ULMACEAE

Ulmus americana L., American elm—*BSS 282* (ALBC, PCCI); *EA s.n.*, *MV 5* (PCCI). C, upland and lowland forests, thickets, borders, old fields, and open wetlands.

Ulmus rubra Muhl., slippery elm—*BSS 2066* (MICH, PCCI). F, dry-mesic and mesic forests, especially young, weedy stands and borders.

URTICACEAE

Boehmeria cylindrica (L.) Sw., false nettle—*BSS 187* (ALBC, PCCI). F, shores, sedge meadows, and open swamps.

Laportea canadensis (L.) Wedd., wood nettle—*BSS 210* (ALBC, PCCI). C, upland forests and swamps.

Parietaria pensylvanica Willd., pellitory—*BSS 2386* (MICH, PCCI). LC, waste area behind Hyla House.

Pilea fontana (Lunell) Rydb., bog clearweed—*JDS 4073* (ALBC, PCCI). F, ± open wetlands and shores.

Pilea pumila (L.) A. Gray, clearweed—*BSS 2506* (PCCI). LC, shaded two-track around Whitefish Lake and possibly overlooked elsewhere.

Urtica dioica L., stinging nettle—*BSS 211*, *JDS 4061* (ALBC, PCCI). O, disturbed, open ground, but also sporadic in less disturbed forests and wetlands.

VALERIANACEAE

Valeriana uliginosa (Torr. & A. Gray) Rydb., swamp valerian—*BSS 128* (ALBC, PCCI). R, fen along Brewster Lake, possibly extirpated.

VERBENACEAE

Verbena hastata L., blue vervain—*BSS 225* (ALBC, PCCI). F, open wetlands and shores; moist fields and retention ponds. †NW, POND, SE1, SE2.

* *Verbena stricta* Vent., hoary vervain—*BSS 2306* (PCCI). O, old fields, clearings, roadsides, and waste areas, at least in part waifs from plantings. †HP, LT, N, NE, SE2, SP.

Verbena urticifolia L., white vervain—*BSS 2325* (PCCI). F, old fields, thickets, forest borders, and disturbed open ground.

VIOLACEAE

Viola affinis Le Conte, Le Conte's violet—*BSS 2032* (PCCI). C, the most abundant and characteristic "stemless blue" violet in upland forests throughout.

* *Viola arvensis* Murray, field pansy—*BSS 2569* (PCCI). R, flowerbeds on main campus.

Viola blanda Willd., sweet white violet—*BSS 1* (ALBC, PCCI). O, wet thickets.

Viola canadensis L., Canada violet—*JLL 120* (BALT), *BSS 32* (ALBC, PCCI). LC, mature upland forests.

Viola cucullata Aiton, marsh violet—*BSS 4*, *75* (ALBC, PCCI); *JS 4* (PCCI). C, open swamps, wet thickets, wet meadows, shores, and seeps.

Viola labradorica Schrank, dog violet—*BSS 3*, *JDS 4021* (ALBC, PCCI). F, copses, moist thickets, and shrubby wetlands.

Viola nephrophylla Greene, northern bog violet—*BSS 2072* (PCCI). O, fairly local in springy open swamp forests.

Viola palmata L., wood violet—*BSS 2071* (PCCI). R, small colony in isolated wooded copse surrounded by swamp forest.

Viola pubescens Aiton, yellow violet—*BSS 9* (ALBC, PCCI). C, upland forests, primarily mature stands.

Viola rostrata Pursh, long-spurred violet—*BSS 46*, *JDS 4023* (ALBC, PCCI). F, mature (especially beech-maple) forests.

Viola sororia Willd., common blue violet—*BSS 2384* (ALBC, PCCI). R, waste area behind Hyla House. Possibly overlooked elsewhere. An additional collection from a "marsh on E side of Cedar Creek" (*JLL 124*, BALT) was not examined but is likely one of the other blue-flowered species more typical of wetlands.

Viola striata Aiton, cream violet—*BSS 2* (ALBC, PCCI), *JS 2* (PCCI). O, moist thickets.

VITACEAE

Parthenocissus inserta (A. Kern.) Fritsch, thicket creeper—*BSS 2317* (PCCI). O, old fields, thickets, and forest borders.

Parthenocissus quinquefolia (L.) Planch., Virginia creeper—*BSS 364* (ALBC). A, widespread and abundant, especially in disturbed, ± wooded habitats.

Vitis aestivalis Michx., summer grape—*BSS 2214* (PCCI). F, upland forests and borders.

Vitis labrusca L., fox grape—*JDS 4062* (ALBC, PCCI). R, N side of Cloverdale Road.

Vitis riparia Michx., river-bank grape—*JDS 4091* (ALBC, PCCI), *JF s.n.* (PCCI). C, widespread in a variety of upland and lowland habitats.

APPENDIX 2. Species excluded from the inventory but introduced in plantings or landscaping as observed by the author, represented in herbarium collections, or reported in Howell and Lucas (2018). Since plantings were not inventoried for this study, the following list may be incomplete, may include species that failed to establish following their introduction, and may contain inaccuracies.

Introduced species are indicated with an asterisk (*) preceding the scientific name. Species without an asterisk are considered native to Michigan (MICHIGAN FLORA ONLINE 2011) but are not necessarily native to PCCI (see annotations). Collections are indicated by collector initials, collection number, and location of specimens, following Index Herbariorum (Thiers 2018). Collectors are as follows: BSS (Bradford S. Slaughter); JDS (J. Dan Skean, Jr.); MV (Michael VanDyken). Herbaria are as follows: ALBC (Albion College); MICH (University of Michigan); PCCI (unofficial designation for Pierce Cedar Creek Institute).

For each species listed below, a dagger (†) and list of associated locations as reported in Howell and Lucas (2018) is indicated. Locations of plantings are as follows: BA (Batts Cottage); BL (Brewster Lake); C (Central Prairie); CAM (Campus); FB (Fire Breaks); HP (Hedgerow Prairie); LT (Lupine Trail Prairie); ME (Middle East Prairie); MON (Monarch Waystations); MW (Middle West Prairie); N (North Prairie); NE (North East Prairie); NW (North West Prairie); RP (Retention Ponds); SE1 (Southeast Prairie 1); SE2 (Southeast Prairie 2); SP (Sand Prairie); SW (South West Prairie); TR (Trails); WOOD (North Prairie Young Forest); YF (Tall Grass Prairie Trail Young Forest).

CONIFERS

TAXACEAE

**Taxus baccata* L., English yew. †BA. *BSS 311* (ALBC, PCCI); reported in Slaughter and Skean 2003b).

ANGIOSPERMS (FLOWERING PLANTS)

MONOCOTS

AMARYLLIDACEAE

Allium cernuum Roth, nodding wild onion. †LT, SE1, SP.
Allium tricoccum Aiton, ramps. †WOOD. Native at Little Grand Canyon.

COMMELINACEAE

Tradescantia ohiensis Raf., common spiderwort. †H, LT, N.

CYPERACEAE

Carex davisii Schwein. & Torr., Davis' sedge. †WOOD. **SPECIAL CONCERN.**
Carex gracilescens Steud., sedge. †WOOD.
Carex grayi J. Carey, sedge. †WOOD.
Carex jamesii Schwein., James' sedge. †WOOD.

POACEAE

Bouteloua curtipendula (Michx.) Torr., side-oats grama. †H, LT, NE, NW, SE2, SP. **ENDANGERED**.
Diarrhena obovata (Gleason) Brandenburg, beak grass. †WOOD. **THREATENED**.
Elymus canadensis L., Canada wild rye. †H, ME, MW, N, NW, SE1, SW.
Koeleria macrantha (Ledeb.) Schult., June grass. †LT, SP.
Sporobolus cryptandrus (Torr.) A. Gray, sand dropseed. †H, ME, MW, SE1, SW.
Sporobolus heterolepis (A. Gray) A. Gray, prairie dropseed. †H, LT. **SPECIAL CONCERN**.

SMILACACEAE

Smilax lasioneura Hook., carrion-flower. †WOOD.

EUDICOTS

APIACEAE

Eryngium yuccifolium Michx., rattlesnake-master. †H, LT, MW, N, NW, SE1, SP. **THREATENED**.

Zizia aptera (A. Gray) Fernald, prairie golden alexanders. †H. **THREATENED**.

ARALIACEAE

Aralia racemosa L., spikenard. †WOOD. Native at Little Grand Canyon.

ASTERACEAE

Antennaria neglecta Greene, cat's foot. †SP.
Brickellia eupatorioides (L.) Shinners, false boneset. †LT. **SPECIAL CONCERN**.
Coreopsis lanceolata L., sand coreopsis. †H, LT, N, NE, NW, SE2.
Coreopsis palmata Nutt., prairie coreopsis. †H. **THREATENED**.
Coreopsis tripteris L., tall coreopsis. †H.
**Echinacea pallida* Nutt., pale coneflower. †H, LT.
Echinacea purpurea (L.) Moench, purple coneflower. †MW, N, NE, SE1, SE2. **EXTIRPATED**.
Eupatorium sessilifolium L., upland boneset. †H. **THREATENED**.
Eutrochium purpureum (L.) E. E. Lamont, green-stemmed Joe-pye-weed. †WOOD. Native at Little Grand Canyon.
**Helianthus laevigatus* Torr. & A. Gray, smooth sunflower. †LT.
**Helianthus maximiliani* Schrad., Maximilian sunflower. †H.
Helianthus occidentalis Riddell, western sunflower. †SE1.
Heliopsis helianthoides (L.) Sweet, false sunflower. †H, ME, MW, NE, NW, SE1, SE2, SW. *MV 28* (PCCI).
Liatris aspera Michx., rough blazing-star. †N, SP.
**Liatris pycnostachya* Michx., prairie blazing-star. †H, ME, MW, NW, SE1, SW.
**Liatris* sp. †LT. Listed as "western blazingstar" in Howell and Lucas (2018).
Packera obovata (Willd.) W. A. Weber & Á. Löve, round-leaved ragwort. †LT. Native at Little Grand Canyon (*BSS 734*, MICH).
Packera paupercula Michx., balsam ragwort. †LT.
**Parthenium integrifolium* L., wild quinine. †H, NW.
Prenanthes alba L., white lettuce. †WOOD.
Rudbeckia triloba L., three-lobed coneflower. †H, LT, ME, NE, SE2, SW.
Silphium integrifolium Michx., rosin weed. †H, N, NW. **THREATENED**.
Silphium laciniatum L., compass plant. †H, N, NW, SE1. **THREATENED**.
Silphium perfoliatum L., cup plant. †H, NE, SE2. **THREATENED**.
Silphium terebinthinaceum Jacq., prairie-dock. †H, NW, SE1.
Solidago rigida L., stiff goldenrod. †H, LT, NW.
Solidago speciosa Nutt., showy goldenrod. †LT.
Solidago ulmifolia Willd., elm-leaved goldenrod. †WOOD.
Symphyotrichum laeve (L.) G. L. Nesom, smooth aster. †H, LT.
Symphyotrichum oolentangiense (Riddell) G. L. Nesom, sky-blue aster. †H, LT, SP.

BERBERIDACEAE

Caulophyllum thalictroides (L.) Michx., blue cohosh. †WOOD. Native at Little Grand Canyon.

BETULACEAE

Betula nigra L., river birch. †RP.
Betula populifolia Marshall, gray birch. †BA, RP. *BSS 433* (ALBC), *JDS 4044* (ALBC, PCCI), *MV 11* (PCCI); reported as *B. pendula* in Slaughter and Skean (2003b). **SPECIAL CONCERN**.

BORAGINACEAE

Hydrophyllum appendiculatum Michx., great waterleaf. †WOOD. Native at Little Grand Canyon (*BSS 735*, MICH).
Mertensia virginica (L.) Pers., Virginia bluebells. †WOOD. **ENDANGERED**.

CAMPANULACEAE

Campanula rotundifolia L., harebell. †LT.

EUPHORBIACEAE

Euphorbia corollata L., flowering spurge. †LT, SP.

FABACEAE

Amorpha canescens Pursh, lead-plant. †H, LT, ME, MW, N, SE1, SP, SW. **SPECIAL CONCERN**.

Baptisia lactea (Raf.) Thieret, white false indigo. †H, LT, MW, N, NW, SE1. **SPECIAL CONCERN**.

Baptisia leucophaea Nutt., cream wild indigo. †H, LT. **ENDANGERED**.

Chamaecrista fasciculata (Michx.) Greene, partridge-pea. †H.

Dalea purpurea Vent., purple prairie-clover. †H, LT. **EXTIRPATED**.

Desmodium canadense (L.) DC., showy tick-trefoil. †H, ME, MW, NW, SE1, SW.

Lespedeza capitata Michx., round-headed bush-clover. †H, ME, MW, SE1, SW.

Lupinus perennis L., wild lupine. †H, LT, ME, MW, N, NE, SE1, SE2, SP, SW.

FAGACEAE

Castanea dentata (Marshall) Borkh., American chestnut. †CAM. **ENDANGERED**. Outside native range at PCCI.

HYANGEACEAE

**Philadelphus* sp. †CAM. Research Lab.

LAMIACEAE

Monarda punctata L., horse mint. †LT.

Pycnanthemum pilosum Nutt., hairy mountain mint. †WOOD. **THREATENED**.

Pycnanthemum virginianum (L.) Durand & Jackson, common mountain mint. †H.

OLEACEAE

**Forsythia suspensa* (Thunb.) Vahl, weeping forsythia. †TR. *JDS 4150* (ALBC); reported in Slaughter and Skean (2003b).

PAEONIACEAE

**Paeonia lactiflora* Pall., Chinese peony. †TR. *JDS 4236* (ALBC); reported in Slaughter and Skean (2003b).

PLANTAGINACEAE

Penstemon digitalis Nutt., foxglove beard-tongue. †H, NW. *BSS 2234* (PCCI). Not clearly established outside plantings.

Penstemon hirsutus (L.) Willd., hairy beard-tongue. †H, LT, ME, MW, N, NE, SE1, SE2, SW.

Veronicastrum virginicum (L.) Farw., culver's-root. †SE1.

POLEMONIACEAE

Polemonium reptans L., Jacob's-ladder. †WOOD. **THREATENED**.

RANUNCULACEAE

**Actaea racemosa* L., black snakeroot. †WOOD. Listed as *Cimicifuga racemosa* in Howell and Lucas (2018).

Anemone cylindrica A. Gray, thimbleweed. †LT, SE1.

RHAMNACEAE

Ceanothus americanus L., New Jersey tea. †H, LT, SP.

ROSACEAE

Drymocallis arguta (Pursh) Rydb., tall cinquefoil. †H, MW, N.

Filipendula rubra (Hill) B. L. Rob., queen-of-the-prairie. †RP. **THREATENED**.

Geum triflorum Pursh, prairie-smoke. †MW, SE1, SP. **THREATENED**.

**Prunus armeniaca* L., apricot. †TR. *BSS 316* (ALBC, PCCI).

SAPINDACEAE

**Acer platanoides* L., Norway maple. †BA. *JDS 4069* (ALBC, PCCI); reported in Slaughter and Skean (2003b).

SCROPHULARIACEAE

Scrophularia lanceolata Small, early figwort. †WOOD.

RESPONSE OF 25 RARE PLANT SPECIES ON ROCKY SHORELINES OF ISLE ROYALE NATIONAL PARK IN THE FACE OF EXTREME WATER LEVELS IN LAKE SUPERIOR

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ABSTRACT

Arctic and alpine rare plant species populate wave-splashed rocky shorelines of Isle Royale National Park, where summer temperatures are moderated by Lake Superior. Using data from the mid-1990s and resurvey data from 1998, 2003, and 2016, we examined trajectories of change in occurrence for 25 species at 28 sites coincident with rising lake levels that followed a period of sustained low levels. We analyzed changes in site occupancy of species individually and by functional, geographic, and microhabitat groupings. We also assessed change in population structure for four focal species. Of the 25 species, site occupancy increased for 13, and remained steady for six, declining in another six. Site occupancy did not change over time within functional, geographic, and microhabitat groupings. The four focal species increased in all measures of abundance from low- to high-water periods, reflecting dynamic and systematically changing populations responding to similar ecological exposures. These findings support the idea that the moderating influence of Lake Superior on air temperatures benefits these populations, despite warming temperatures and a 15-year sustained low water period, and contribute to our understanding of the responses of at-risk species to extreme climate events.
KEYWORDS: Disjunct, *Pinguicula vulgaris*, *Saxifraga paniculata*, *Saxifraga tricuspidata*, *Vaccinium uliginosum*

INTRODUCTION

The cold, upwelling waters of Lake Superior provide refugia for small suites of both Arctic and alpine disjunct plant species (Given and Soper 1981). Populations of these species are found in a limited number of rocky shoreline habitats on islands and along the north shore of the lake (Soper and Maycock 1963; Marr et al. 2009; Zlonis and Gross 2018) (Table 1). Perhaps most notably, Isle Royale National Park ("Isle Royale" or the "Park"), located in northwest Lake Superior, is host to several dozen rare species with distributions typically more common at higher latitudes and altitudes.

On Isle Royale and elsewhere around Lake Superior, many of these species opportunistically grow in narrow veins of soil that form in rock cracks, or on thin

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TABLE 1. Conservation status of the 25 species in this study according to Michigan Natural Features Inventory (MNFI 2017) (MNFI) for Michigan and to NatureServe (2017) for Michigan, Minnesota, Wisconsin, Ontario, the US, Canada, and globally. The MNFI categories are endangered (E), threatened (T), and special concern (SC). The NatureServe categories are critically imperiled (1), imperiled (2), vulnerable (3) apparently secure (4), and secure (5). These numbers are prefaced by the letters S, N, or G for state, national, or global ranks, respectively. A "?" indicates an inexact or uncertain rank. A range rank (N#N# or S#S#) indicates uncertainty about the exact status; a T# following the G# or an asterisk in a state or province ranking indicates that the status applies to subspecies or varieties.

		NatureServe Status						
Scientific name and authority	**MNFI**	**Mich**	**Minn**	**Wis**	**Ont**	**USA**	**Canada**	**Global**
Allium schoenoprasum L.	T	S2	S2	unranked	S4	N3N5	N5	G5
Bistorta vivipara (L.) Delarbre	T	S1S2	S3	not present	S5	unranked	N5	G5
Carex atratiformis Britton	T	S2	not present	not present	S2	unranked	N4N5	G5
Carex gynocrates Wormsk. ex Drejer	not listed	unranked	unranked	S4	S5	unranked	N5	G5
Carex media R.Br.	T	S2S3	unranked	S2	S4S5	unranked	N5	G5T5
Castilleja septentrionalis Lindl.	T	S2S3	S1	not present	S5	unranked	N5	G5
Cryptogramma acrostichoides R.Br.	T	S2	not present	not present	S2S3	unranked	N5	G5
Draba arabisans Michx.	SC	S3	S3	S2	S4	unranked	N4N5	G4
Drosera anglica Huds.	SC	S3	S3	S1	S5	unranked	N5	G5
Empetrum nigrum L.	T	S2	S1	not present	S5	N5	N5	G5
Euphrasia hudsoniana Fernald & Wiegand	T	S1	S3	not present	S4?	unranked	N4N5	G5?
Huperzia selago (L.) Bernh. ex schrank & Mart.	SC	S3	unranked	S1S2	S4	unranked	N5	G5
Lonicera involucrata (Richardson) Banks ex Spreng.	T	S2*	not present	S1	S5	unranked	N5	G5T4T5
Packera indecora (Greene) A. Löve & D. Löve	T	S1	S3	S1	S5	unranked	N5	G5
Parnassia palustris L.	T	unranked	unranked	unranked	unranked	unranked	N5	G5
Pinguicula vulgaris L.	SC	S3	S3	S1	S5	unranked	N5	G5
Poa alpina L.	T	S1S2	unranked	not present	S4	unranked	N5	G5
Sagina nodosa (L.) Fenzl	T	S2	S1	not present	S4	N3N4	N5	G5
Saxifraga paniculata Mill.	T	S1	S2	not present	S4	N2	N4N5	G5
Saxifraga tricuspidata Rottb.	T	S2	not present	not present	S4	unranked	N5	G5
Tofieldia pusilla (Michx.) Pers.	T	S2	S1	not present	S5	unranked	N5	G5
Triantha glutinosa Baker	not listed	unranked	S4S5	S2S3	S4?	unranked	N5	G5
Trisetum spicatum (L.) K. Richt.	SC	S2S3	S4S5	S2	S4	unranked	N5	G5
Vaccinium uliginosum L.	T	S2	S2	not present	S5	unranked	N5	G5
Vaccinium vitis-idaea L.	E	S1	unranked	S1S2*	S5	unranked	N5	G5T5

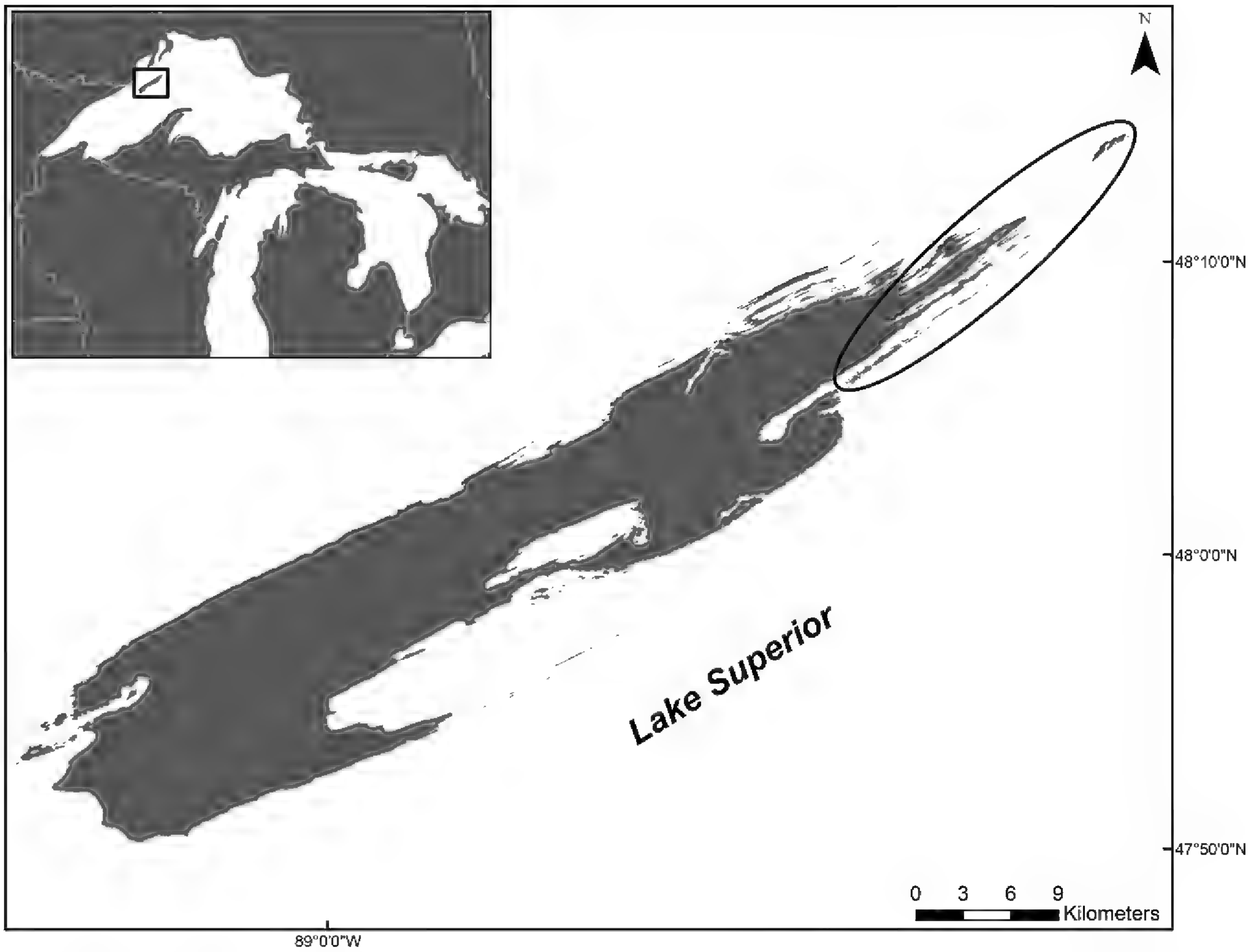

FIGURE 1. Inset: Location of Isle Royale National Park in Lake Superior and the Great Lakes. Main map: Isle Royale with the study area, shown circled to the northeast (ESRI Basemap 2019).

cryptobiotic crusts. Some species occur at the margins of rock pool wetlands that have formed in rock depressions (Judziewicz 1999). Isle Royale's rocky headlands, which dominate both the northeast coast of the main island and numerous barrier islands, are directly exposed to the wind and wave action of the open lake (Figure 1). As a result, changes in lake level and storm events impact the availability of water to plants via the height of wave splash and rock pool recharge.

Lake Superior water levels are dynamic and are largely influenced by the regional climate (Stow et al. 2008). The Lake Superior region experienced warming temperatures, increased evaporation, and intermittent declines in precipitation from the late 1990s to the early 2010s due to a strong El Niño event, so that Lake Superior levels dropped (Assel et al. 2004; Gronewold and Stow 2014). Water levels remained below the 100-year mean from 1998 to 2013, the longest such period (15 years) since 1918, when the collection of long-term data begins (USACE 2020) (Figure 2).

Coincident with this extreme low water period, three censuses of the distribution and abundance of Isle Royale's rocky shoreline rare plant communities were made in 1993–1994, 1998, and 2003 (Judziewicz 1995, 1999, 2004). Subsequent to the 2003 census, the height of Lake Superior dropped to its lowest level in 85 years before rising to levels above the 100-year mean in 2014 (Figure 2), setting a record for the most rapid rise in levels over a 2-year period

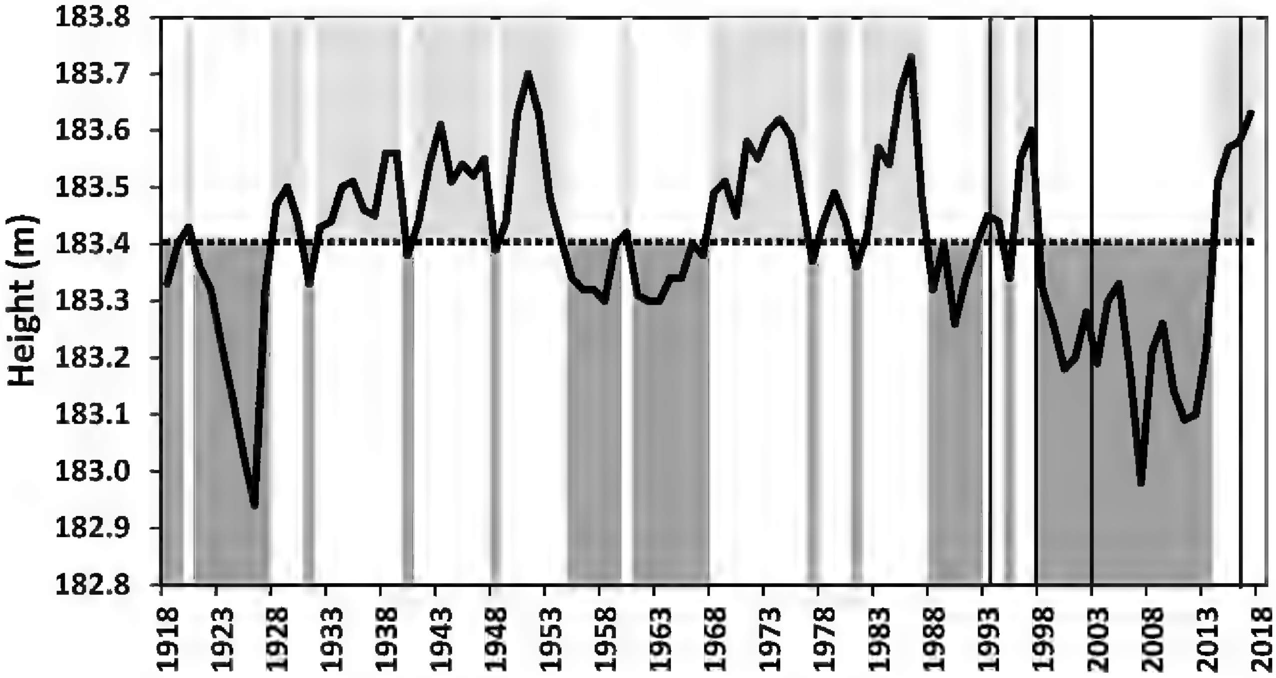

FIGURE 2. Lake Superior water levels, expressed as meters above sea level, during the period from 1918 to 2018 (USACE 2020). The horizontal dashed line represents the 100-year mean; the vertical solid lines represent the four sampling events. Gray bars highlight the duration of periods above and below the long-term mean water level.

(Gronewold et al. 2016). Water levels were still above the long-term average in 2016, coinciding with our most recent plant recensus as reported in this paper.

Many of the rare rocky outcrop species at Isle Royale National Park are at or near their distribution limits; as such, conditions may already be marginal for them (Lawton 1993; Curnutt et al. 1996), and any additional stresses brought on by low lake levels could lead to losses of populations and extirpation from the Park. We undertook the present work to examine changes in populations of rare Arctic and alpine species of Lake Superior rocky shorelines on Isle Royale, concurrent with long-term low lake levels. We examined site-level trajectories of change in occurrence for 25 species, individually and in functional and microhabitat groupings based on pollination mechanism, dispersal distance, degree of clonality, vertical distribution above the lake, and geographic range position. These groupings were selected because they may inform us about the ability of species to persist and spread in response to warming and future lake level variation. We also tested for differences in measures of abundance of four focal species between the initial and final censuses. These four species were chosen, because they are generally more apparent and widespread across the survey area than the other species in this study. Understanding their responses on Isle Royale could provide information to managers, conservationists, and researchers that is applicable across the broader distributions of these species.

MATERIALS AND METHODS

Study Area

Isle Royale (Figure 1) is an archipelago in Lake Superior composed of one large island (72 km long, 14 km wide) and more than 400 smaller barrier islands. Their general orientation is a northeast-

southwest direction with parallel, erosion-resistant basalt ridges (Thornberry-Erlich 2008). Jurisdictionally, the Park is a part of Keweenaw County, Michigan.

Many of the Park's rare plant species are located on the exposed rocky headlands and cliffs of the main island and the barrier islands at the northeast end of the park (Slavic and Janke 1987; Figure 1). These headlands provide sunny microhabitats exposed to the temperature-moderating effects of Lake Superior (Given and Soper 1981), water recharge from the lake, and shelter from prevailing west winds due to the land mass of the main island (Judziewicz 1995). Soil formation is negligible here and is restricted to cracks, crevices, and other low depressions. Cryptobiotic crusts provide thin organic surfaces which are often colonized by a suite of more widespread species (e.g., *Campanula rotundifolia* L., *Achillea millefolium* L., *Solidago hispida* Muhl. ex Willd.) that are adapted to the stresses of sun exposure, ice heaving, and relatively low nutrient availability.

Xeric species occupy the most exposed faces of these rocky headlands, while hydrophytes occupy rock pools that form in crevices and depressions. The most xeric microhabitats support species dependent on occasional wave splash, precipitation, and probably fog (Larson et al. 2000; Fischer et al. 2009; Marr et al. 2009), such as *Saxifraga paniculata* and *Trisetum spicatum*. Rock pools within most headland areas provide habitat for *Sphagnum* spp. and wetland species such as *Trichophorum cespistosum* (L.) Hartm., *Drosera rotundifolia* L., and *Pinguicula vulgaris* (Slavik and Janke 1987). Due to the heterogeneity among rock pool locations, the water budgets of these rock pools vary in their hydrologic input sources (Smith 1983). Some pools are precipitation-dominated via snowmelt and rainfall, some are exposed to Lake Superior wave splash, some receive runoff inputs from higher points on the island, some are in groundwater seepage areas, and some are influenced by multiple hydrologic inputs (Egan et al. 2015). Water levels are the most consistent in seepage area pools and in pools at lower elevations relative to Lake Superior.

While some species in the rocky shoreline community of Isle Royale have distributions well south of Lake Superior, several have broad northerly distributions and are circum-Arctic or circumboreal. Some taxa represent disjunct populations of Arctic or alpine species at the far southern extent of their range (Table 2), while others are disjunct from western or northwest North America populations. Climate-driven glaciation and glacial retreats during the Quaternary period facilitated disjunctions in some species (Comes and Kadereit 1998). For example, research indicates that two of our focal species, *Vaccinium uliginosum* (Alsos et al. 2005) and *Saxifraga paniculata* (Reisch 2008), expanded post-glaciation northward into the Arctic via dispersal from refuge sites they occupied during glaciation. Be it due to dispersal events after glaciation or to refuge sites that remained after range contractions during glaciation, the timing and causes of disjunction should not be assumed to be the same among all taxa in our study (Thorne 1972).

Plant Censuses

Judziewicz (1995) conducted baseline field censuses for 102 rare plant species in 1993 and 1994. He chose locations based on known occurrences of rare plant species from earlier botanical surveys, known habitat preferences, and interpretation of aerial imagery. These area-wide censuses were conducted in both early and late season; thus, his data encompass the fruiting and flowering periods for most of the target species. Judziewicz's approach to quantifying abundance depended on the species and its growth habitat. For example, both *Saxifraga paniculata* and *S. tricuspidata* form cushions which are composed of multiple rosettes (McGuire and Armbruster 1991; Reisch 2008; Medeiros et al. 2012). While uncertainty about genetic identity of individual rosettes exists (McGuire and Armbruster 1991), Judziewicz (2004) followed Reisch et al. (2003) and recognized cushions as genetically unique individuals, or "genets", and the rosettes comprising these cushions as clones of one-another, or "ramets" (Dr. E. Judziewicz, personal communication, May 17, 2016). In these instances, data include counts of both ramets and genets, as well as reproductive stems. In the case of *Pinguicula vulgaris*, vegetative reproduction is prolific, and there is no visual method to discern genetic differences. In this instance, all rosettes were considered ramets. For other species that have a prostrate or spreading growth habit (e.g., *Empetrum nigrum*, *Vaccinium uliginosum*), he made ocular estimates of the area occupied in m^2. In several instances, Judziewicz noted only presence or absence. In collaboration with the National Park Service, he established and permanently marked 28 locations where he found target rare species. Sites were loosely defined as areas supporting rare plants and located on separate islands from one another, or on the mainland, separated by at least 300 meters. The sizes of the sites varied to include the entirety of the rare plants present, in most cases, unless he

TABLE 2. Rare species included in the present study and their functional groups for three plant traits, for microhabitat type, and for position in geographic range. A position in the range is not assigned to *Cryptogramma acrostichoides*, because Isle Royale is the only documented location within the study's range criteria.

Species	Pollination mechanism	Dispersal distance	Clonality	Microhabitat type	Position in range
Allium schoenoprasum	Biotic	Local	Short distance	Splash zone	Northern
Bistorta vivipara	Biotic	Local	Short distance	Splash zone	Southern
Carex atratiformis	Abiotic	Widespread	Not clonal	Splash zone	Southern
Carex gynocrates	Abiotic	Widespread	Long distance	Peaty shore	Southern
Carex media	Abiotic	Widespread	Not clonal	Rock pool	Southern
Castilleja septentrionalis	Biotic	Local	Not clonal	Forest edge	Central
Cryptogramma acrostichoides	Abiotic	Widespread	Not clonal	Lichen zone	
Draba arabisans	Biotic	Widespread	Long distance	Lichen zone	Central
Drosera anglica	Biotic	Widespread	Short distance	Rock pool	Central
Empetrum nigrum	Abiotic	Widespread	Long distance	Lichen zone	Southern
Euphrasia hudsoniana	Biotic	Local	Not clonal	Rock pool	Southern
Huperzia selago	Abiotic	Widespread	Short distance	Lichen zone	Southern
Lonicera involucrata	Biotic	Widespread	Not clonal	Forest edge	Central
Packera indecora	Biotic	Widespread	Not clonal	Lichen zone	Central
Parnassia palustris	Biotic	Widespread	Not clonal	Peaty shore	Central
Pinguicula vulgaris	Biotic	Widespread	Long distance	Rock pool	Southern
Poa alpina	Abiotic	Widespread	Not clonal	Forest edge	Southern
Sagina nodosa	Biotic	Widespread	Clonal	Splash zone	Central
Saxifraga paniculata	Biotic	Local	Short distance	Lichen zone	Southern
Saxifraga tricuspidata	Biotic	Local	Not clonal	Lichen zone	Southern
Tofieldia pusilla	Biotic	Local	Short distance	Rock pool	Southern
Triantha glutinosa	Biotic	Local	Not clonal	Rock pool	Central
Trisetum spicatum	Abiotic	Widespread	Not clonal	Lichen zone	Southern
Vaccinium uliginosum	Biotic	Widespread	Long distance	Rock pool	Southern
Vaccinium vitis-idaea	Biotic	Widespread	Long distance	Lichen zone	Southern

noted a constrained census area. He revisited and collected similar data at these 28 plots in 1998 (Judziewicz 1999) and 2003 (Judziewicz 2004).

We resampled the 28 permanent plots between July 6 and August 1, 2016 to maximize the probability that plants were flowering or fruiting and applied area-wide census searches to count or measure all individuals present for any of the 25 target species (Table 2). We a priori chose four focal species for more intensive population metrics. Judziewicz's surveys in 1998 and 2003 most consistently included demographic data across all plots for these four species, which are generally more abundant and apparent than the others. Applying similar methods as Judziewicz, we counted the number of ramets (rosettes), genets (cushions), and reproductive stems of *Saxifraga paniculata* and *S. tricuspidata* at all sites where they were located. For *Pinguicula vulgaris*, a highly clonal species, we recorded the total number of ramets (rosettes). We estimated areal coverage for *Vaccinium uliginosum*.

Data Summaries and Analyses

The availability of quantitative data from the earlier surveys varies among species, years, and sites. In some instances, only presence is noted while in others, detailed counts of both reproductive and non-reproductive individuals were recorded. Site occupancy data, however, are standard and comparable among years and species in the long-term data set. For each of the 25 target species, we summed the number of sites occupied by each species during each census and examined the magnitude and direction of change in site occupancy between the initial and final censuses.

We then identified five, broad, functional, geographic, and microhabitat groups that could potentially further explain site occupancy: pollination mechanism, dispersal distance, degree of clonality,

vertical distribution above Lake Superior, and geographic range position (Table 2). Some levels within these categorical groups (e.g., abiotic and biotic pollination or long and short distance dispersal; see below) may indicate species traits that contribute to the persistence, expansion, or contraction of a population over time. Using literature searches and our knowledge of the species' biology, we classified species into levels for each group (Table 2). For each of the five groups of interest, we summed site occupancy (the number of sites a given species was present) across species, within each level. In each group, we then compared these sums across the four censuses, the three by Judziewicz in 1993–1994, 1998, and 2003, and our sampling in 2016.

To group species by pollination mechanism, we classified species as biotically pollinated if they contained any specialized attractants, such as colorful flowers. Otherwise, species were classified as abiotically pollinated. For dispersal distance, we considered species to be capable of widespread dispersal if the fruits have adaptations for wind, water, fur, or animal gut dispersal. Otherwise, dispersal was considered local. We categorized the degree of clonality as short distance if the species is capable of vegetative reproduction with only a very limited distance from the parent plant (e.g., adventitious buds). We categorized some taxa as having long distance clonality if there are adaptations for further spread (e.g., rhizomes, stolons, bulbils). Species were considered not clonal if they were capable of only sexual reproduction.

Most of the species here occupy key niches within the rocky shorelines, so we categorized species by their microhabitat or vertical position and relative influence by Lake Superior (Table 2). For example, among our target species, *Sagina nodosa* is largely limited to rock cervices in the lowest elevation habitat <4 meters (slope distance) from the calm weather waterline, which we categorized as the "splash zone" of Lake Superior. Other species also growing near the waterline but in isolated pockets of perpetually wet soil were placed in the "peaty shore" microhabitat. *Pinguicula vulgaris* and *Drosera anglica* are largely confined to the edges of small rock pools. For these and other species occupying a similar niche, we designated the microhabitat as "rock pool." Some species, such as *Trisetum spicatum*, occupy cracks in the basalt in relatively more upland microhabitats that receive less frequent splash from Lake Superior. These upland areas of exposed rock are lichen-covered, and soil formation is minimal, so we refer to this microhabitat as the "lichen zone." Finally, the lichen zone transitions to a shrub (i.e., *Juniperus communis* L.) and forested zone, and species such as *Saxifraga tricuspidata* occupy this transition zone, which we refer to as the "forest edge."

To categorize species within their broader geographical ranges, we determined whether the Isle Royale populations were in the southern, central, or northern third of the species ranges in eastern North America (Table 2). Using the online data portals of Canadensys (2017), Consortium of Midwestern Herbaria (2017), and Consortium of Northeastern Herbaria (2017), we recorded the most northern and southern records for each species. Because populations in mainland Europe and western North America are subject to vastly different temperature patterns from those in central and eastern North America and Greenland, we considered only North American records east of the 100° meridian west and in Greenland. We computed range thirds from UTM northing values for each species. In some instances, herbarium reports at the southern end suggest adventive individuals (e.g., a record of *Lonicera involucrata* in the city of Washington D.C., "near fence gate"). These were not included. We also did not include *Cryptogramma acrostichoides* in this classification, because the Isle Royale populations, which are disjunct from the main range of this species in western North America, were the only ones within the study area.

For the four focal species with complete abundance records, we evaluated the change in abundance from prior to the 15-year drop in lake level (1990s) to 2016 after the lake levels rose again. For *Saxifraga* spp., we assessed the abundance of ramets, genets, and reproductive stems, while for *Pinguicula vulgaris*, we assessed only the abundance of ramets due to limited data on reproductive status in the historical records. For *Vaccinium uliginosum*, we tested for change in areal coverage. We computed the annual percentage change for most metrics using the formula ((2016 value–1993 value) / 1993 value * 100)) / 22 years (in some cases 1994 was the baseline year). We applied non-parametric permutation tests (R, coin package) to test for differences in abundances between years. These tests do not require assumptions of equal variance between groups and normality of errors; as such, they are applicable here, where sample sizes are small and assumptions of parametric tests cannot be met. In most instances, the baseline time period was from the 1993/94 census, however in three instances where earlier data were not available, once for *P. vulgaris* and twice for *V. uliginosum*, we instead used 1998 as the baseline year. The number of site-census year pairs tested for

TABLE 3. The number of sites in which rare species were observed in 1993/94 and their site occupancy in those same sites in subsequent years. Numbers in parentheses indicate the total site occupancy including additional sites where those species were not recorded as observed in previous censuses. Direction arrows indicate either gain, loss, or no net change between the first and last sampling event, including any additional sites.

Species	1993/94	1998	2003	2016	Direction
Allium schoenoprasum	1	1	1	1 (3)	↑
Bistorta vivipara	3	2	2	2	↓
Carex atratiformis	2	1	3	2	↔
Carex gynocrates	1	0	0	0	↓
Carex media	3	1	1	2(4)	↑
Castilleja septentrionalis	3	3	1	3(5)	↑
Cryptogramma acrostichoides	2	1	2	2	↔
Draba arabisans	2	2	3(4)	4(5)	↑
Drosera anglica	1	1	1	1	↔
Empetrum nigrum	8	8	8	8(10)	↑
Euphrasia hudsoniana	2	1	0	0(1)	↓
Huperzia selago	2	2	1(2)	1(3)	↑
Lonicera involucrata	1	1	1	1	↔
Packera indecora	4	2	2	3	↓
Parnassia palustris	2	2	0	0	↓
Pinguicula vulgaris	11	9	12(15)	11(16)	↑
Poa alpina	4	2	2	2(3)	↓
Sagina nodosa	2	2(3)	2	2(4)	↑
Saxifraga paniculata	6	7	7	8(9)	↑
Saxifraga tricuspidata	9	7	10	9	↔
Tofieldia pusilla	3	3	2	1(3)	↔
Triantha glutinosa	2	3	3	5(9)	↑
Trisetum spicatum	8	6(8)	7(12)	12(19)	↑
Vaccinium uliginosum	13	12	14	13(16)	↑
Vaccinium vitis-idaea	1	1	1	1(2)	↑

each species was eight (*Saxifraga paniculata*), nine (*S. tricuspidata*), nine (*P. vulgaris*), and 14 (*V. uliginosum*). Continued persistence of these populations is of management significance, so detecting any potential decline is paramount, and we are less concerned about making a Type I error (concluding that population decline exists even when it does not) than a Type II error (concluding that there is no change in abundance when, in fact, change has occurred). For this reason, we considered significance as $P \leq 0.1$.

RESULTS

The 25 rare plant species surveyed in 2016 were dispersed over the 28 monitoring sites (n=3.4 rare species/site). Site occupancy increased for 13 species and remained steady for six species. Six species underwent losses in the number of sites occupied (Table 3). In most cases, functional, microhabitat, and geographic groupings of taxa showed little change in site occupancy between the censuses (Figure 3). Biotically pollinated species composed over two-thirds of the site occupancy, regardless of year (Figure 3a). Likewise, species with widespread dispersal represented nearly two-thirds of the species-site combinations for all years (Figure 3b). At all censuses, species which are not clonal were generally slightly

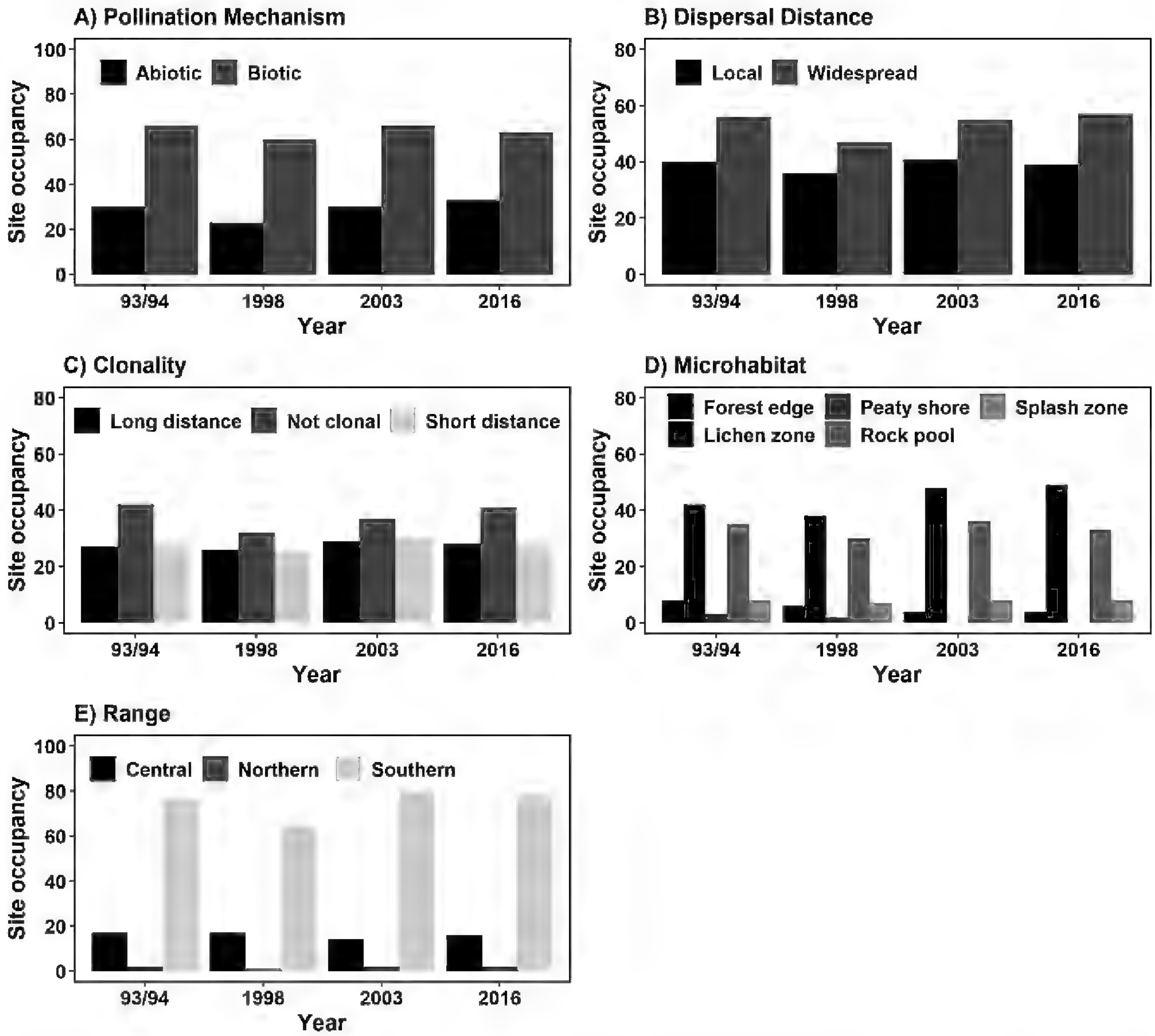

FIGURE 3. Site occupancy across sample years, grouped by life history traits (a-c), their local habitat niches (d), and geographic range position at Isle Royale National Park (e). Y-axis represents the number of sites a given species was located, summed across all species within that level-year combination. *Cryptogramma acrostichoides* is not included in range location since it is the only location of this species within the study area.

more common at sites than species capable of either long or short distance clonality (Figure 3c). The lichen zone and rock pools are more frequently occupied by rare species than other microhabitats within sites (Figure 3d). Throughout all sample periods, most of the rare species occurrences are of species in the southern third of their ranges (Figure 3e).

While change over time was not linear, basal rosette (ramet) numbers for the three herbaceous focal species increased between the early 1990s and 2016 (Figure 4, Table 4) at an annual growth rate of from 9.8% (*Saxifraga paniculata*) to almost 14% (*Saxifraga tricuspidata* and *Pinguicula vulgaris*). Despite four times as many total ramets observed for *S. tricuspidata* in 2016 compared to the early 1990s (Figure 4, Table 4), mean ramet number among sites was not statistically greater (Table 5). The only decline in abundance that occurred during the low water period (2003) was in the areal coverage of *Vaccinium uliginosum* (Figure

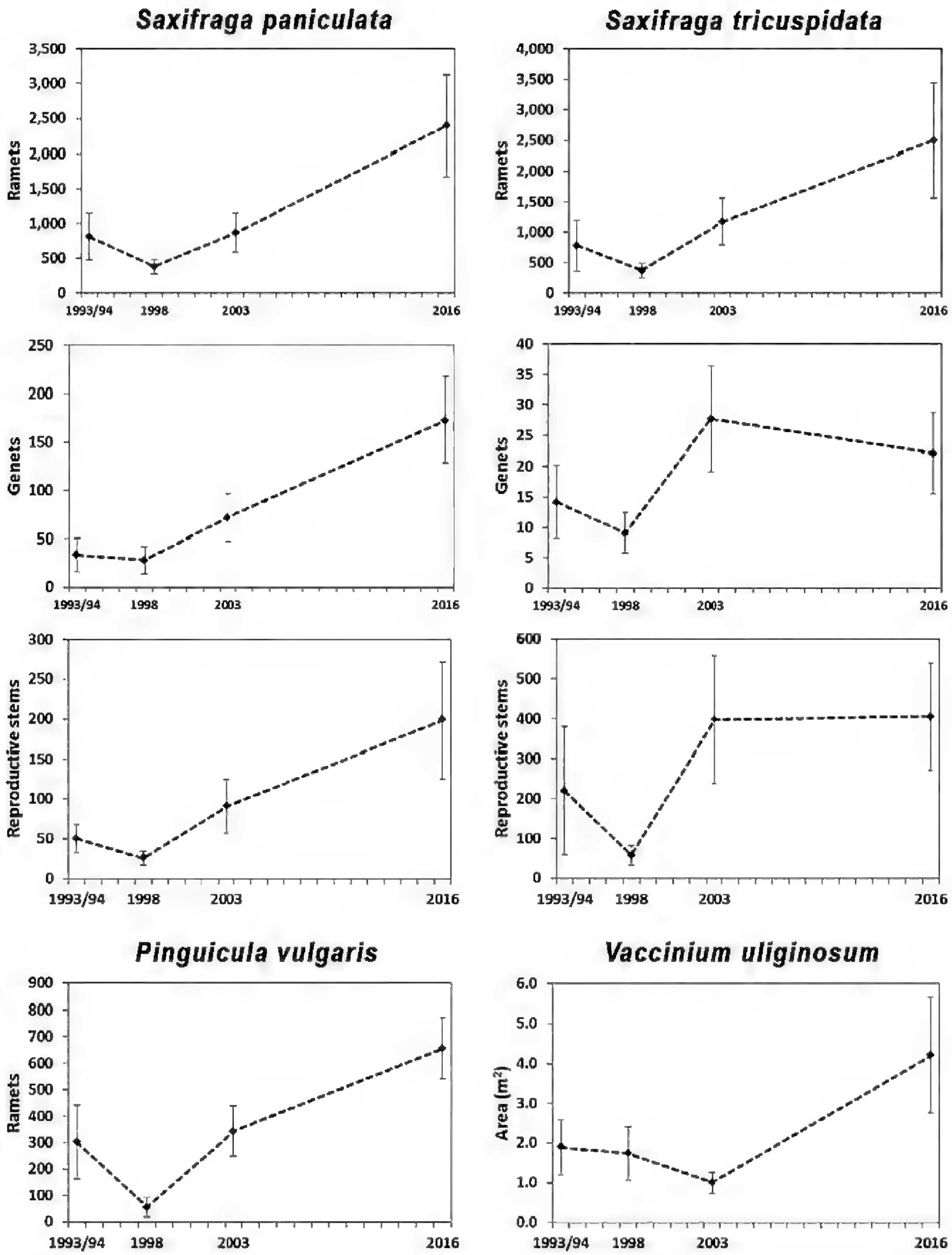

FIGURE 4. Mean number of ramets, genets, and reproductive stems of *Saxifraga paniculata* and *S. tricuspidata*, mean number of ramets of *Pinguicula vulgaris*, and mean area occupied by *Vaccinium uliginosa* for sites of the four focal species across all study years. Error bars represent ± 1 s.e. Permutation tests compared only one pre-low water level time (typically 1993/94) against the 2016 value.

TABLE 4. Population metrics across all sites in each sample period for the four focal species for which consistent quantitative abundance data were available.

Sample Period	Total Number of Ramets	Total Number of Genets	Number of Reproductive Stems	Percentage of Reproductive Stems	Total Areal Coverage (m^2)
Saxifraga paniculata					
1993/94	4,757	186	263	5.53	
1998	2,807	190	170	6.06	
2003	5,642	450	610	10.81	
2016	15,009	1,060	1,230	8.20	
Saxifraga tricuspidata					
1993/94	6,245	113	1,755	28.10	
1998	3,346	82	515	15.39	
2003	11,714	277	3,977	33.95	
2016	24,977	221	4,046	16.20	
Pinguicula vulgaris					
1993/94	2,417	222	9.18		
1998	506	164	32.41		
2003	4,799	1,332	27.76		
2016	9,829	2,789	28.38		
Vaccinium uliginosum					
1993/94					22.75
1998					24.40
2003					13.97
2016					63.07

4, Table 4), but this species had an overall trend of increase at a 8% annual growth rate from the early 1990s to 2016. While average areal coverage of *Vaccinium uliginosum* was $2m^2$ greater in 2016 than in 1993/94, high variability among populations precluded significant differences (Figure 4; Table 5). The mean plant population size (number of genets) of the lichen zone species *S. paniculata* was five times larger in 2016 than was observed in 1993/94 (Figure 4, Table 4), representing a 21.4% annual growth rate. Similarly, the average number of reproductive stems was almost five times greater in 2016 for *S. paniculata* (Figure 4, Table 4), but less than 10% of all ramets were reproductive. The number of reproductive stems of the rock pool species *P. vulgaris* increased from 9% to 28% during this time period (Table 4). The forest edge species *S. tricuspidata* had greater variability among populations in some years, so increases observed

TABLE 5. *P*-values for permutation tests for site-year pairs by species. An asterisk indicates significance at $\alpha = 0.1$.

Species	Ramets	Genets	Reproductive stems	Area
Saxifraga paniculata	0.0551*	0.0324*	0.0781*	—
Saxifraga tricuspidata	0.1377	0.3300	0.4006	—
Pinguicula vulgaris	0.0230*	—	—	—
Vaccinium uliginosum	—	—	—	0.1312

in average ramet number, genets, and counts of reproductive stems in 2016 were not statistically greater than baseline numbers (Figure 4; Table 5).

DISCUSSION

Our work detailing the population trends of rare species on Isle Royale shows that the majority of these species (19 of 25) are either remaining stable or experiencing expanding population structure. This must be interpreted cautiously, however, as the number of individuals and sites supporting each of these species remains small. The more detailed data on population structures that we collected on the four focal species tend to support the idea of modest growth. While permutation tests showed changes (increases) in only four of the eight species-metric measures of abundance, we recognize that the small number of these populations can limit statistical power to detect change. Actual values of site occupancy and abundance are generally of more interest to managers; in our case, we observed sizeable increases in all measures of abundance for all four focal species. Across all 25 species, the success of the majority of species we observed in 2016 after a 13-year sampling hiatus was surprising given a 15-year low water level concomitant with rising air temperatures, increased evaporation, and intermittently lower precipitation regionally (Gronewold et al. 2016; Zhong et al. 2016), coupled with the fact that these species generally grow farther north or at higher altitudes than Isle Royale. Air and water temperatures have both risen over the 25 years of this monitoring, with lake temperatures warming faster (Austin and Colman 2008). Nonetheless, temperature moderation of coastal habitats by Lake Superior may be limiting the effects of warming temperatures.

Lake Superior hydrology may be playing a large role regulating the occurrence and population sizes of these rare species via changes in lake levels. Water levels are determined by a number of natural inputs and outputs (precipitation, stream input, groundwater, surface water runoff, and evaporation (Gronewold et al. 2016)) as well as limited water level regulation, which is managed by the International Joint Commission and currently follows the Lake Superior Regulation Plan 2012 (International Joint Commission 2012). Lake Superior water levels have fluctuated since 1918, with an average water height of 183.4 m above sea level. These levels were below average from 1998 through 2013, after which levels rose to above-average heights (Figure 2). While the difference between the 1986 high (183.73 m) and the most recent low (182.98 in 2007) is only 0.75 m, this can significantly impact the amount of bedrock either exposed or submerged, as these headlands are low and with gradual slopes into the lake. The increase in lake level and increases in precipitation between 2013 and 2016 (Gronewold et al. 2016) could explain the relatively successful response of species in 2016, as long-established populations are once again in closer proximity to water recharge and to the temperature-moderating influence of moister coastal conditions.

Rocky shoreline species, while presumably weak competitors, generally possess physiological and anatomical adaptations that confer tolerance against stress

(Maestre et al. 2009; Pellissier et al. 2010). *Saxifraga paniculata*, in particular, displays a number of these traits associated with water stress, including leaf cupping (Neuner et al. 2008) and a thick cuticle (Hegi 1975). This species also displays leaf hydathodes, an adaptation to, among other things, high summer temperatures often present on limestone substrates (Andrei and Paraschivoiu 2008). This adaptation creates a cooler, more humid atmosphere around the plant (Andrei and Paraschivoiu 2008), but also allows direct uptake of snowmelt (see Hacker and Neuner 2006) and possibly rainwater and moisture from fog.

The ability to absorb moisture from the air may also exist in *Pinguicula*, a genus of carnivorous species with specialized glands on the lower leaf surfaces (Lloyd 1942; Adlassnig et al. 2005), although we are unaware whether this has been demonstrated. The favorable performance of *P. vulgaris* may be more a function of its dispersal mechanism. Like most carnivorous plants, *P. vulgaris* possesses only a weak root system (Adlassnig et al. 2005); in autumn, a winter bud (hybernaculum) is produced with several gemmae around the base (Heslop-Harrison 2004). Running water or, in the case of Isle Royale, wave action can dislodge gemmae, allowing them to disperse to and colonize new rock pools (Legendre 2000). The 0.75 m rise in water level may have allowed wave action to reach extant colonies which had experienced either limited, or no high velocity wave action for several years. Expanded rock pool habitat may also have occurred with increased water levels.

Despite the numerous positive changes, six species experienced overall losses in the number of sites occupied (population contraction) over the entirety of the study period. It is likely that several factors contributed to changes for each species. One of the declining species, *Bistorta vivipara*, is known to have a low seed set and slow, conservative growth (Diggle 1997); five growing seasons are required between leaf and inflorescence initiation to reach functional maturity. As a consequence, the current season's above-ground appearance reflects environmental conditions of the previous four years; likewise, poor environmental conditions during one year could impact five years of plant performance. Reproduction is primarily asexual, by bulbils, and successful fruit set has only rarely been reported in the literature (see Diggle et al. 2002 for citations). In North America, fruit set in the subalpine environment has been reported only in Wyoming (Bliss 1958). Reasons for the low fruit set include low pollen viability (Engell 1978; Diggle et al. 2002) and high rates of embryo abortion, possibly due to genetic abnormalities (Diggle et al. 2002). Reproduction by bulbils may be adaptive in cold environments (Billings and Mooney 1968) by reducing reliance on pollinators and allowing dispersion of successful genotypes away from the parent plant. Like many of the species in this study, however, Isle Royale populations are highly isolated from other populations outside of the Park, and often even from one another within the archipelago. Lack of genetic recombination on a regular basis would limit the ability of *Bistorta vivipara* to adapt at the southern edge of its distribution where conditions are likely sub-optimal (Reed and Frankham 2003; Spielman et al. 2004).

Like *Bistorta vivipara*, *Poa alpina* also reproduces by both bulbils and seed and also experienced a decline over the 24-year study period with two of the four sites extirpated. Research in North America (Hermesh and Acharya 1987) has

demonstrated temperature-specific adaptation for a number of reproductive characteristics, including the number of florets per panicle. In an Alpine environment in Europe, Steiner et al. (2012) found plastic responses of *P. alpina* in response to transplantations across elevations. Although we are unaware of the relative proportion of seed vs. bulbil production for Isle Royale populations, collectively, these suggest *Poa alpina* should be able to either adapt or acclimate to environmental conditions there.

The ability to adapt may be greater for annual species, as a result of more frequent genetic recombination, although distances between populations could also be prohibiting this. One of the species that fared the poorest over the 24-year study period is *Euphrasia hudsoniana*, originally present at two locations. This appears to have been extirpated from the sites where it was originally known, although it was subsequently found in 2016 at a site not previously occupied by this species. Zlonis and Gross (2018) examined the genetic structure of this species on the rocky shoreline of Lake Superior in northern Minnesota. They demonstrated a high degree of heterozygosity within populations, which may be a result of its tetraploid genome (Meirmans and Van Tienderen 2013). While this level of heterozygosity should promote population persistence, the distances separating known populations will inhibit, or even prevent, gene flow between them. Ultimately, such isolation may be rendering this species unable to adapt to changing environmental conditions.

Of the species that performed well, two—*Sagina nodosa* and *Trisetum spicatum*—were particularly surprising to us. *Sagina nodosa* grows just above the waterline and typically occupies the lowest niche on the rocks. Because of this, we may have anticipated a downward migration of existing populations over the low water period, followed by a loss of these populations as the water level rose to above-average depths after 2013. Instead, we found a net increase in populations. In addition, although abundance data are not available for all sites at all time periods, where data are available, we found marked increases in the number of stems in total, as well as those that were reproductive (data not shown). *Sagina nodosa* produces vegetative buds on the stem which disarticulate; these float and are carried by wind and water to potential new colonization sites (Wright 1953). This form of reproduction and dispersal is highly adaptive in this environment and will likely serve this species well in the face of future potential fluctuating water levels.

The grass species *Trisetum spicatum* is also performing well in the Park. While we do not have abundance data for all sites and censuses, the abundance of both genets and reproductive stems generally increased ten-fold at sites where data are available (data not shown). In addition, we often noticed this species growing in several areas along the rocky coastlines outside of established sampling sites. Unfortunately, little is known about the biology of this species that could inform us of the causes for this increase.

Piecing together the biological basis for change in rare species can be challenging, and rare species sampling efforts themselves also present unique challenges. In earlier sampling efforts in the absence of aerial imagery, maps were often hand drawn, and GPS was often either unavailable or unreliable, making relocation inexact, although, Judziewicz's (1999) maps and notations about sam-

ple locations were quite detailed. Differences between observers also introduces uncertainty (Alexander et al. 2012; Morrison and Young 2016); these differences can be between sampling events or from within the same event. Finally, although rare, the few populations where a species is present are sometimes comprised of large numbers of genets or ramets, which also introduces some degree of error in complete census counts, especially when, as in some instances, hundreds of ramets are present. For the current work, we acknowledge a degree of uncertainty when counting ramets and assessing areal coverage, including for all four focal species. However, counts of genets and reproductive stems were much more straightforward, since these were fewer and more clearly defined. We note here that the relative patterns of abundance of both genets and reproductive stems largely mirror those of ramet abundance for the first three time periods of this study (Figure 4, a small dip in abundance in 1998, followed by a sizeable increase in 2003). In our current census (2016), we see a similar pattern, where marked increases in ramets are concordant with more genets and reproductive stems, providing further assurance that the large increases we observed in 2016 are genuine. Finally, the three earlier censuses were completed by Judziewicz (1995, 1999, 2004), who author S. Johnson assisted elsewhere to monitor rare plants using similar methods. Because Johnson was at all sampling locations and times in 2016, we have assurance that techniques and practices of the 2016 event were fairly consistent with those of earlier censuses.

We recognize that factors besides lake level may be playing into species performance, particularly locally. Unfortunately, we lack site-level data on temperature and solar radiation; likewise, the record for precipitation at the park is incomplete. Because of these shortfalls, we are unable to test for correlations of these metrics with population response. However, what this work does show is that, despite a 16-year record of low water, the majority of these species are as abundant, or even more abundant, than prior to the drop in water level. Our work here, which represents a single snapshot in time, suggests that these species possess a degree of resilience to ecosystem stressors that we had, perhaps, not anticipated. The continued fate of these populations, of course, remains unseen.

Research Needs and Management Recommendations

For the majority of species studied here, we lack detailed information on basic biology (Godefroid et al. 2011). Understanding the breeding system, population genetic structure, anatomy (as it relates to growth and development), and physiology (responses to temperature and solar irradiation) would help guide any future management action and/or development of restoration plans. Thorough, updated inventories of all potentially suitable habitat is also desired.

At this point in time, we urge park managers to explore seedbanking for some of these species. Retaining seed not only conserves genetic material, but provides sources for ex-situ research, as suggested above. We also suggest that Isle Royale managers initiate dialog with their counterparts at other parks around Lake Superior that support these species. For populations with limited genetic diversity, reciprocal outplanting of seed (or vegetative material) between them may be required to avoid local extinction.

While the idea of working to preserve these species is noble, in reality, options to manage these species will be limited in the face of continuing climate change. By and large, these species are adapted to cooler, moist conditions with less solar irradiation, concomitant with northern latitudes. They have most likely persisted due to the moderating effects of Lake Superior and available rocky shoreline habitat. As air and water temperatures continue to rise, suitable habitat within the Park may cease to exist. Managing foot traffic in high visitor use areas (e.g., Scoville Point on the main island) could limit trampling of species such as *Saxifraga tricuspidata* and *Empetrum nigrum*. Removing non-native wetland species (*T. angustifolia* L. and its hybrid with the native *T. latifolia* L.) from rock pools may serve to protect habitat for rare species such as *Carex media* R.Br. At the upper edge of their habitat, succession to shrubs and forest may overcome habitat for populations of species such as *S. tricuspidata* and *E. nigrum*, so maintaining more open conditions in some sites is an option to retain regenerating populations of these rare species. Managing for other species is not as clear-cut. While we have every interest in preserving natural resources within the National Park system, one may question the prudence of this, given the current climate forecasts, the difficulties encountered during rare species reintroductions, and the fiscal demands of such efforts (Godefroid et al. 2011). Nonetheless, what we propose here is still of value. Several of these species have widespread distributions and documenting their changes in occurrence in Isle Royale may signal species-scale distributional shifts related to climate change. Documenting changes in rare species may cue managers of the risk of deeper ecosystem changes. Knowledge gained of breeding systems, physiology, and genetic structure of these species could be applied not only to managers on Isle Royale, but to practicing conservationists elsewhere.

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BRYOPHYTES OF BUTTERNUT PINES, OCONTO COUNTY, WISCONSIN

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ABSTRACT

We present the results of a bryological survey of the 40-acre Butternut Pines property in Oconto County, northeastern Wisconsin. Field work from 1993 to 2019 resulted in the collection and identification of 299 bryophyte specimens. 111 species of bryophytes were identified, including 20 species of liverworts and 91 species of mosses; of these, 11 species of liverworts and 72 species of mosses represent first published reports for Oconto County, and bring the county's total bryoflora to 128 species. For its size, Butternut Pines has one of the most diverse published bryofloras in the midwestern United States, apparently exceeded only by Woodman Hollow State Preserve in Webster County, Iowa.
KEYWORDS: Oconto County, Wisconsin, bryophytes.

INTRODUCTION

This paper presents the results of a bryological survey of Butternut Pines, a 40-acre tract of land owned by the second author and Wyat D. Judziewicz located in Oconto County in northeastern Wisconsin (Town of Breed, T30N-R17E, Sec. 14, NE4 of NE4, 45°30′N, 86°46′W) on the North Branch of the Oconto River about 70 km northwest of the city of Green Bay and 60 km west of Marinette, Wisconsin (Figure 1). A complete description of the plant communities and vascular flora of the tract from 1975 to 2002 was presented by Judziewicz (2004) and updated through 2020 by Judziewicz and Zaborsky (in prep.). The following plant communities are present at Butternut Pines (Judziewicz 2004), based on the classification of Curtis (1961): alder thicket, bracken grassland, northern dry forest, northern dry-mesic forest, northern mesic forest, northern wet-mesic forest, pine barrens, southern sedge meadow (approaching northern sedge meadow and even calcareous fen in places), and south-

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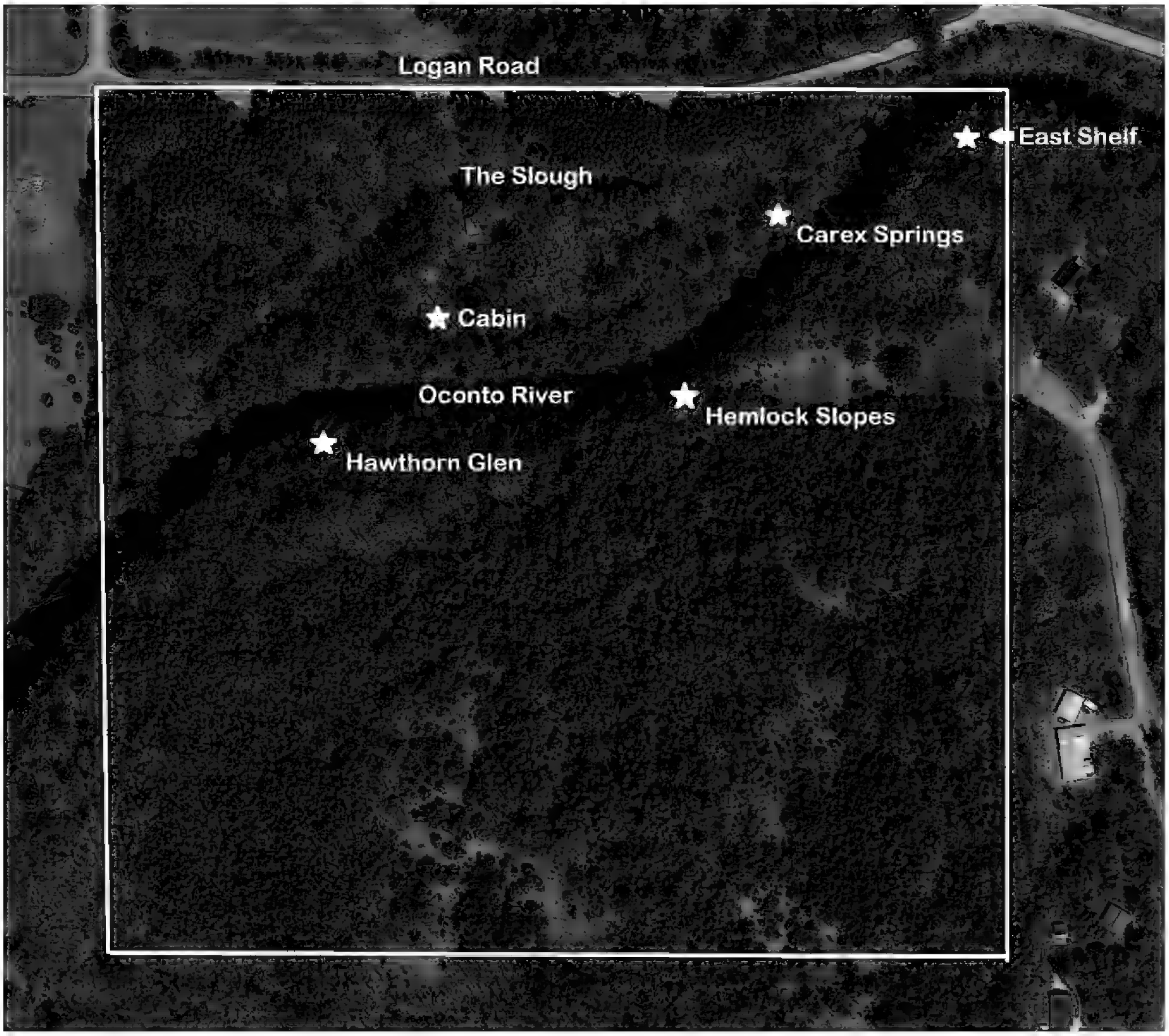

FIGURE 1. Map of Butternut Pines, showing the principal collecting localities. The location of the tract is in the Town of Breed, T30N-R17E, Sec. 14, NE4 of NE4, 45°30′N, 86°46′W, Oconto County, Wisconsin, and it is ¼ mile long on each side. Google Earth image taken on May 17, 2018.

ern wet forest (floodplain forest). The dominant upland community is northern dry-mesic forest dominated by white pine (*Pinus strobus* L.), red oak (*Quercus rubra* L.), red maple (*Acer rubrum* L.), white birch (*Betula papyrifera* Marshall), and quaking aspen (*Populus tremuloides* Michx.); the dominant trees along the south side of the Oconto River, on the moist, steep, shaded, bryophyte-rich, north-facing riverbank, are white cedar (*Thuja occidentalis* L.) and eastern hemlock (*Tsuga canadensis* (L.) Carrière).

MATERIALS AND METHODS

A total of 299 bryophyte specimens were collected at Butternut Pines from 1993 to 2019. A complete set of specimens is deposited at the Robert W. Freckmann Herbarium (UWSP) at the University of Wisconsin-Stevens Point in Stevens Point, Wisconsin; most of the Judziewicz collections from 1993 and 1994 have duplicates at the Wisconsin State Herbarium in Madison (WIS). Ninety-four specimens were collected by Judziewicz on March 2 and April 28, 1993; March 29, April 13, 15, and 25, 1994, and one collection on November 2, 1995. Freire collected 69 specimens on May 6 and 7, 2006. Freire and Judziewicz collected on September 16-17, 2019 and on September 24, 2019,

for a total of 135 collections including “segregates” (for example, collection number BP-17 consists of four segregates BP-17a, 17b, 17c, and 17d; these four species are so intricately entangled that it would be inordinately time-consuming to separate them, hence the need to maintain them in one packet under one collection number with a, b, c, and d segregate designations). Most of the 1993 and 1994 specimens were identified by Bowers; Freire’s specimens were identified using Schuster (1953), Crum (1991, 2004), and, in a few instances, the Flora of North America Editorial Committee (2007, 2014). Nomenclature, including familial dispositions, follows the Flora of North America Editorial Committee (2007, 2014) for mosses, and Stotler and Crandall-Stotler (2017) for liverworts.

We also wanted to estimate how diverse the bryoflora of Butternut Pines is compared with other midwestern U.S. areas that have had bryological surveys. To answer this question, we performed an extensive literature search of published Wisconsin bryofloras (Rose 2019) as well as all other available bryofloras for counties and parks in other states of the Upper Midwest (Illinois, Iowa, Michigan, and Minnesota). The data for each site’s area and observed number of species was log-transformed, plotted on a graph, and then a least-squares regression line was fitted to the data using Social Science Statistics (2020). The regression line was then used to generate a species-area relationship (Mitchell and Ryan 2001) for midwestern United States bryophytes, presented in the results section, in an attempt to set Butternut Pines in the context of regional bryofloras.

RESULTS

Our collections at Butternut Pines resulted in the following list of bryophytes for the site. An asterisk (*) preceding the name indicates that the species represents a new Oconto County record, according to Rose (2019) and the Consortium of North American Bryophyte Herbaria (2020). Collection numbers in the 10,000s are by Judziewicz in 1993 and 1994. Collection 11,720 is by Judziewicz in November 1995. Collection numbers with the prefix “BP-” are by Freire in 2006 (numbers through BP-53) or by Freire and Judziewicz in 2019 (numbers BP-100 and above).

LIVERWORTS

ADELANTHACEAE

**Syzygiella autumnalis* (DC.) K. Feldberg, Váňa, Hentschel & Heinrichs, BP-47, BP-186b, decorticate log near driveway.

ANEURACEAE

**Aneura pinguis* (L.) Dumort. BP-207, bare soil on East Shelf.

CEPHALOZIACEAE

**Cephalozia bicuspidata* (L.) Dumort. BP-22a.

Fuscocephaloziopsis lunulifolia (Dumort.) Váňa & L.Söderstr. 10812 (WIS), Occasional, moist bases of riverbank hardwoods; BP-189b, Slough margin north of cabin.

**Nowellia curvifolia* (L.) Dumort. 10822 (WIS), rotted log near cabin; 10848 (WIS), base of large red maple near Logan Road; BP-2, BP-10d, BP-43a, BP-53, BP-186a. Common.

CONOCEPHALACEAE

**Conocephalum salebrosum* Szweyk., Buczk. & Odrzyk. 10094 (WIS), fen-like riverside seep, Carex Springs; BP-4a. Common on moist shaded riverbanks.

FRULLANIACEAE

**Frullania bolanderi* Aust. BP-204, trunk of red maple, East Shelf.

Frullania brittoniae A. Evans. BP-8; BP-201, on basswood trunk, East Shelf.

Frullania eboracensis Gottsche. BP-1a, BP-50, south side of river; BP-202, on trunk of black ash, East Shelf.

**Frullania inflata* Gottsche. BP-194, rotted American elm (*Ulmus americana* L.) trunk near cabin; BP-195, quaking aspen trunk near cabin; BP-205, trunk of red maple, East Shelf.

Frullania riparia Hampe. BP-105, on tree trunk, East Shelf.

GEOCALYCACEAE

Geocalyx graveolens (Schrad.) Nees. BP-10b, BP-38.

LOPHOCOLEACEAE

**Chiloscyphus polyanthos* (L.) Corda. BP-10a; BP-22b.

Chiloscyphus profundus (Nees) J.J. Engel & R.M. Schust. 10821 (WIS), decorticate log near cabin; BP-10c; BP-22c, BP-35.

MARCHANTIACEAE

**Preissia quadrata* (Scop.) Nees. BP-136, on soil near riverbank, East Shelf.

PELLIACEAE

Pellia sp. BP-137a, on rich floodplain soil in hardwood forest within 1-2 m of riverbank, East Shelf.

**Pellia megaspora* R.M. Schust. BP-216, soil on south riverbank about 50 m west of Hawthorn Glen.

PLAGIOCHILACEAE

Plagiochila porelloides (Nees) Lindenb. BP-120, BP-121, BP-123, East Shelf; BP-163b, Hawthorn Glen; 10795 (WIS), 4 sq. m patch on steep, south-facing, open riverside.

PORELLACEAE

Porella platyphylla (L.) Pfeiff. 11720 (WIS), trunk of large basswood by river; BP-25c, BP-48; BP-100, BP-115a, BP-115b. Abundant.

PTILIDIACEAE

Ptilidium pulcherrimum (G. Weber) Hampe. 10827b, 10828 (WIS), trunk of young white pine near garage; 10850a (WIS), decorticate pine log, 10853 (WIS), decorticate log; BP-147.

RADULACEAE

**Radula complanata* (L.) Dumort. BP-5B, BP-27, BP-125, BP-128, fairly common, East Shelf.

MOSSES

AMBLYSTEGIACEAE

**Amblystegium serpens* (Hedw.) Schimp. BP-4B; BP-171, Carex Springs.

**Campyliadelphus chrysophyllus* (Brid.) Kanda. BP-176b, on soil by river, Carex Springs.

**Campylophyllum hispidulum* (Brid.) Hedenäs. 10805 (WIS), open riverside mucky seep; 10817c, dead willow branch, Carex Springs; BP-5a, BP-16b, BP-23.

**Hygroamblystegium varium* (Hedw.) Monk. var. *humile* (P. Beauv.) Vanderp. & Hedenäs. 10809, common, tree trunk bases; BP-16; BP-162, Hawthorn Glen fen.

**Leptodictyum riparium* (Hedw.) Warnst. BP-117, soil at base of tree trunk by river on steep, shaded slope.

**Pseudocampylium radicale* (P. Beauv.) Vanderp. & Hedenäs. 10844 (WIS), mucky riverbank; BP-191, emergent from shallow water in central Slough; BP-129, East Shelf.

**Sanionia uncinata* (Hedw.) Loeske. 10855 (WIS), local, acidic semi-shade of red pines (*Pinus resinosa* Ait.) along Logan Road.

ANOMODONTACEAE

**Anomodon attenuatus* (Hedw.) Huebener. 10075 (WIS), on bark of black ash. BP-114, East Shelf; BP-185b, on white cedar bark, Carex Springs; BP-215b, East Shelf.

Anomodon minor (Hedw.) Lindb. 10818 (WIS), decorticate log at Carex Springs, also BP-185a; BP-1b, north of river near cabin; BP-11a, BP-20; BP-26.

**Anomodon rostratus* (Hedw.) Schimp. 10819 (WIS), rotted bark, base of dead basswood at Carex Springs.

**Anomodon rugelii* (Müll. Hal.) Keissl. BP-105a, East Shelf.

BARTRAMIACEAE

**Bartramia pomiformis* Hedw. 10076 (WIS), earth bank; 10798 (WIS), steep, N-facing riverbank; with *Buxbaumia aphylla*; same site, BP-150.

BRACHYTHECIACEAE

**Brachythecium* sp., either *B. acutum* (Mitt.) Sull., or *B. campestre* (Müll. Hal.) Schimp. 10072 (WIS), 10073, mixed woods on south bank; BP-18a.

**Brachythecium laetum* (Brid.) Schimp. 10824 (WIS), decorticate aspen log near cabin.

Brachythecium rivulare Schimp. 10825 (WIS), terrestrial in willow shrub swale in northwest corner of tract, with *Pleurozium schreberi*; BP-163c, fen-like seep, Hawthorn Glen.

**Brachythecium rutabulum* (Hedw.) Schimp. 10815 (WIS), moist acid ditch along Logan Road, among red pines.

**Brachythecium salebrosum* (F. Weber & D. Mohr) Schimp. 10788 (WIS), common, tree trunk bases; 10800 (WIS), common, rotted logs near cabin; 10803 (WIS), common, tree trunk bases; 10854 (WIS), dominant on drift boulders and tree bases near the Slough; BP-193, common large moss with sporophytes on soil along Slough north of cabin.

**Brachythecium turgidum* (Hartm.) Kindb. 10811 (WIS), common, water's edge of Slough; BP-34; BP-176a, on soil by river, Carex Springs.

**Bryhnia novae-angliae* (Sull. & Lesq.) Grout. 10077 (WIS), earth bank under hemlocks, near *Buxbaumia aphylla*; BP-181, 182, 183, dominant in Carex Springs fen.

**Eurhynchiastrum pulchellum* (Hedw.) Ignatov & Huttunen. BP-25b, BP-46.

**Rhynchostegium serrulatum* (Hedw.) Jaeg. 10808 (WIS), very common, tree trunk base. BP-177, on soil by river, Carex Springs.

**Sciuro−hypnum plumosum* (Hedw.) Ignatov & Huttunen. BP-29a, 32.

**Sciuro−hypnum populeum* (Hedw.) Ignatov & Huttunen. BP-174, tree base at Carex Springs.

BRYACEAE

**Ptychostomum cernuum* (Hedw.) Hornsch. 10845, mucky riverbank.

**Ptychostomum creberrimum* (Taylor) J.R. Spence & H.P. Ramsay. 10847, mucky seeping riverbank southeast of cabin.

**Rhodobryum ontariense* (Kindb.) Paris. 10092 (WIS), log in fen-like seep, Carex Springs; still present (but uncommon) there and at Hawthorn Glen seep in 2019.

BUXBAUMIACEAE

**Buxbaumia aphylla* Hedw. 10078 (WIS), rare on bare soil on steep, north-facing riverbank under hemlocks, with *Bartramia pomiformis*, in 1994; not relocated since. Fifth Wisconsin county record (Rose, 2019).

CLIMACIACEAE

Climacium americanum Brid. BP-160, Hawthorn Glen seep, at former *Sphagnum russowii* site.

**Climacium dendroides* Brid. 10095 (WIS), on log in fen-like riverside seep, Carex Springs; 10787 (WIS), common along Slough. In 2019, occasional and much less common than in the 20th century, BP-190.

DICRANACEAE

**Dicranella heteromalla* (Hedw.) Schimp. 10790, base of white pine trunk, on river, det. Judziewicz, 2019; 10797 (WIS), shaded base of hemlock; BP-31a.

Dicranum montanum Hedw. 10823 (WIS), very common mat-former on tree bases near Slough.

**Dicranum polysetum* Sw. 10814 (WIS), occasional, acid woods.

**Dicranum scoparium* Hedw. 10097a (WIS), common, log in fen-like riverside seep, Carex Springs.

DITRICHACEAE

**Ceratodon purpureus* (Hedw.) Brid. 10087b (WIS), sandy old field above East Shelf; 10796 (WIS), common on roof of cabin.

ENTODONTACEAE

**Entodon seductrix* (Hedw.) Müll. Hal. 10852, base of large red oak near Logan Road; 10816 (WIS), rotted stump at Carex Springs.

FISSIDENTACEAE

**Fissidens adianthoides* Hedw. 10806 (WIS), open mucky riverside seep near cabin; BP-44; BP-179, riverbank, East Shelf.

**Fissidens elegans* Brid. BP-167, fen-like seep, Carex Springs.

**Fissidens osmundioides* Hedw. BP-45.

**Fissidens taxifolius* Hedw. BP-111, 124, 126, 127, 180, common on bank by water's edge, East Shelf.

HYLOCOMIACEAE

**Rhytidiadelphus triquetrus* (Hedw.) Warnst. 10784 (WIS), occasional, forest margins.

Pleurozium schreberi (Willd.) Mitt. 10794 (WIS), abundant in grassy spots under pines; BP-12.

HYPNACEAE

**Callicladium haldanianum* (Grev.) H.A. Crum. 10067 (WIS), base of white birch trunk; 10085 (WIS), decorticate American elm log on East Shelf; 10091 (WIS), aspen stump near cabin; 10799 (WIS), rotted log in pine woods; BP-13, BP-37.

**Homomallium adnatum* (Hedw.) Broth. BP-118, BP-130, on fallen branch on top of hill, East Shelf.

**Hypnum cupressiforme* Hedw. 10820, rotted boards on south side of cabin; 10851 (WIS), base of dead quaking aspen trunk near Logan Road; BP-25a, around cabin; BP-108, tree trunk, East Shelf; BP-189, Slough north of cabin. *Hypnum cupressiforme* and *H. pallescens* were difficult to distinguish from each other using the characters and keys in either Crum (2004) or Flora of North America Editorial Committee (2014); most material appeared to key to *H. cupressiforme*.

**Hypnum curvifolium* Hedw. 10789 (WIS), decorticate log near the Slough; 10826 (WIS), occasional in boggy part of central Slough; 10843 (WIS), seeping muddy bank; BP-113a, East Shelf.

Hypnum lindbergii Mitt. 10071 (WIS), mixed woods on south bank.

**Hypnum pallescens* (Hedw.) P. Beauv. 10068 (WIS), base of dead quaking aspen. See note under *H. cupressiforme*; this specimen had leaves that were not as crowded as those of that species.

Platygyrium repens (Brid.) Schimp. 10801 (WIS), decorticate log near cabin, BP-6, near cabin, BP-24a, BP-106, East Shelf; BP-186c.

**Pseudotaxiphyllum distichaceum* (Mitt.) Z. Iwats. BP-178, on soil by river, Carex Springs; BP-184, Carex Springs, on soil.

**Pseudotaxiphyllum elegans* (Brid.) Z. Iwats. BP-176c, on soil by river, Carex Springs. Fourth Wisconsin county record (Rose, 2019).

**Ptilium crista-castrense* (Hedw.) De Not. 10813 (WIS), occasional, acid woods; BP-165, along Logan Road.

**Pylaisia selwynii* Kindb. BP-49.

**Taxiphyllum deplanatum* (Bruch & Schimp.) M. Fleisch. BP-176d, on soil by river, Carex Springs.

LESKEACEAE

**Haplocladium microphyllum* (Hedw.) Broth. 10817 (WIS), dead willow branch at Carex Springs; 10827a (WIS), rotted aspen stump near cabin.

**Leskea gracilescens* Hedw. BP-25a; BP-206, on bark of 1 m d.b.h. red oak near Hawthorn Glen.

**Leskea polycarpa* Ehrh. 10083 (WIS), on white cedar trunk, south bank of river; BP-11b.

LEUCOBRYACEAE

Leucobryum glaucum (Hedw.) Ångstr. BP-165, rare on 15-year old white pine stump., in 2019. This familiar, easily recognized species was not observed in 1993 to 1995 forays.

LEUCODONTACEAE

**Leucodon andrewsianus* (H.A. Crum & L.E. Anderson) W.D. Reese & L.E. Anderson. BP-210, tree trunk, East Shelf.

MIELICHOFFERIACEAE

**Pohlia cruda* (Hedw.) Lindb. 10082 (WIS), earth bank under hemlocks.

MNIACEAE

**Mnium marginatum* (Dicks.) P. Beauv. 10100b (WIS), seeping riverbank, Carex Springs.

**Mnium spinulosum* Bruch & Schimp. BP-3, BP-20, BP-131, East Shelf.

**Mnium thomsonii* Schimp. BP-109.

**Plagiomnium ciliare* (Müll. Hal.) T.J. Kop. BP-24b, north of river; 10074 (WIS), mixed woods on south bank of river; 10080 (WIS), earth bank under hemlocks.

**Plagiomnium drummondii* (Bruch & Schimp.) T.J. Kop. BP-102, East Shelf.

Plagiomnium cuspidatum (Hedw.) T.J. Kop. 10081, earth bank under hemlocks; 10093 (WIS), on log in fen-like seep, Carex Springs; 10791, common on logs along Slough; 10802 (WIS), common, logs near cabin; BP-18b, BP-29b.

**Rhizomnium appalachianum* T.J. Kop. 10090 (WIS), riverside seep at Hawthorn Glen.

**Rhizomnium punctatum* (Hedw.) T.J. Kop. 10785 (WIS), dead American elm trunk, on Slough; 10804a, steep, moist, open riverbank.

NECKERACEAE

Neckera pennata Hedw. 10849 (WIS), base of red maple near Logan Road. Occasional on East Shelf in 2019.

ORTHOTRICHACEAE

**Orthotrichum obtusifolium* Brid. BP-104b, East Shelf.

**Orthotrichum sordidum* Sull. & Lesq. BP-203, 1.5-2 m up small black ash trunk, East Shelf; BP-215a, East Shelf, fallen branch.

**Ulota crispa* (Hedw.) Brid. 10856, 1 m up from base of quaking aspen, near the Slough; BP-212, fallen from tree on dry bank above East Shelf.

PLAGIOTHECIACEAE

**Plagiothecium cavifolium* (Brid.) Z. Iwats. BP-113b, BP-116, BP-119, East Shelf.

**Plagiothecium denticulatum* (Hedw.) Schimp. BP-107, rich woods, East Shelf.

**Plagiothecium laetum* Schimp. BP-24b, BP-31b, BP-41, BP-134. East Shelf.

POLYTRICHACEAE

Atrichum altecristatum (Renauld & Cardot) Smyth & L.C.R. Smyth. 10079 (WIS), earth bank on hemlocks, with *Bartramia pomiformis* and *Buxbaumia aphylla.*

Atrichum angustatum (Brid.) Bruch & Schimp. 10792, acid ground near cabin.

Atrichum crispulum Bescherelle. BP-39, north side of river.

Atrichum undulatum (Hedw.) P. Beauv. 10807 (WIS), open riverside mucky seep; BP-145, East Shelf; BP-159, BP-163a, common at Hawthorn Glen.

**Polytrichastrum ohioense* (Renauld & Cardot) G.L. Sm. BP-15.

Polytrichum commune Hedw. 10793 (WIS), from acid ground near cabin.

Polytrichum juniperinum Hedw. BP-30.

**Polytrichum piliferum* Hedw. 10086 (WIS), sandy old field above East Shelf; 10087a, sandy old field above East Shelf; BP-19, BP-40. Dominant ground cover in the Scotch pine plantation from the 1970s to 1990s; occasional in 2019 here.

POTTIACEAE

**Barbula unguiculata* Hedw. 10846 (WIS), mucky seeping riverbank southeast of cabin.

**Bryoerythrophyllum recurvirostrum* (Hedw.) P. Chen. 10100a (WIS), sunny seeping riverbank.

**Didymodon rigidulus* Hedw. 10804, steep, moist, open riverbank. Ninth Wisconsin county record (Rose, 2019).

**Weissia controversa* Hedw. BP-33, BP-42b, 43b, north of river near cabin.

SPHAGNACEAE

**Sphagnum russowii* Warnst. 10088, in 1994 (where the second author noted in his collection notebook “long thought extirpated”) in a 10 x 10 cm patch in riverbank seep (Hawthorn Glen), the only location on the property, where known since 1978, but not seen after the 1994 collection, including on visits to its former spot of occurrence in 2006 and 2019.

TETRAPHIDACEAE

**Tetraphis pellucida* Hedw. BP-17, BP-42.

THUIDIACEAE

**Cyrto-hypnum minutulum* (Hedw.) W.R. Buck & H.A. Crum. BP-192, woods along Slough.

Thuidium delicatulum (Hedw.) Schimp. 10089 (WIS), riverside seep; 10097.5, common as cushions in Scotch pine plantation; 10786 (WIS), rotted American elm log, Slough; 10810 (WIS), common, moist conifer woods, along Slough; BP-9, BP-36, BP-112, BP-122, BP-161, BP-175.

TIMMIACEAE

**Timma megapolitana* Hedw. 10084 (WIS), earth under white cedars and hemlocks; BP-18c, north of river.

Bryophyte diversity was greatest along the North Branch of the Oconto River, in several habitats (all described more fully in Judziewicz, 2004; see map of site, Fig. 1):

1. The east-central south bank (Hemlock Slopes), which consists of steep, north-facing, forested, coniferous slopes dominated by eastern hemlock and white cedar. Here only the fifth Wisconsin county record for *Buxbaumia aphylla* occurred (Rose 2019), along with associates *Atrichum altecristatum*, *Bartramia pomiformis*, *Bryhnia novae-angliae*, *Leskea polycarpa*, *Plagiomnium ciliare*, *Pohlia cruda*, and *Timma megapolitana*.
2. The East Shelf, a rich, shaded, floodplain terrace on the south bank of the river on the eastern boundary dominated by basswood (*Tilia americana* L.), ashes (*Fraxinus nigra* Marshall and *F. pensylvanica* Marshall), red maple, and white cedar. This habitat had the thalloid liverworts *Aneura pinguis* and *Preissia quadrata*, and leafy liverworts such as *Chiloscyphus profundus*, *Frullania bolanderi*, *Plagiochila porelloides*, *Porella platyphylla*, and *Radula complanata*. The mosses *Amblystegium serpens*, *Anomodon rostratus, A. rugelii, Brachythecium* species, *Neckera pennata*, *Plagiomnium drummondii*, three species of *Plagiothecium*, and *Thuidium delicatulum* were present, among others.
3. Springy wetlands on both banks. The south bank has a cold seep, Hawthorn Glen, in which grew a small tussock of *Sphagnum russowii*; it was first observed there in 1978 but was not observed after the 1994 collection. *Climacium americanum* still persists at this site, as does *Rhizomnium appalachianum*. The thalloid liverwort *Pellia megaspora* was present on the riverbank nearby.
4. The north bank, near the northeastern corner of the tract, also features a calcareous seep, Carex Springs, with the mosses *Bryoerythrophyllum recurvirostrum*, *Campylophyllum hispidulum, Dicranum scoparium*, *Mnium marginatum, Plagiomnium cuspidatum*, *Rhizomnium punctatum, Rhodobryum ontariense*, and *Thuidium delicatulum*, and the liverworts *Conocephalum salebrosum* and *Plagiochila porelloides*.

The Slough (Judziewicz 2004), a shaded wetland/tag alder (*Alnus incana* (L.) Moench subsp. *rugosa* (Du Roi) R.T.Clausen) thicket that is an ancient channel of the Oconto River found north of the river, had the following mosses:

Brachythecium laetum, *B. rivulare*, *B. salebrosum, Cyrto-hypnum minutulum*, *Hypnum curvifolium,* and *Pseudocampylium radicale.*

The list includes 91 species of mosses and 20 species of liverworts for a total of 111 bryophyte species. Eleven species of liverworts and 72 species of mosses represent new published reports for Oconto County, according to the online records of Rose (2019) and the Consortium of North American Bryophyte Herbaria (2020) website; it should be noted that many of the second author's 1993-1994 Butternut Pines bryophyte collections have previously appeared on these websites. The first bryophytes were collected in Oconto County by William L. Culberson in 1952, and the county now has 128 documented species of bryophytes (ranking 25th among Wisconsin's 72 counties), up from only 21 species listed by Bowers and Freckmann (1979), and 89 species listed by Rose (2019). If 40-acre Butternut Pines were itself a county, it would rank 27th among the state's 72 counties, based on the map in Rose (2019).

The only other bryophytes previously documented from Oconto County, Wisconsin (Rose 2019; Consortium of North American Bryophyte Herbaria 2020) and not found at Butternut Pines, are the following species, along with their families, collectors, collection numbers, and places of disposition:

Liverworts:

Bazzania trilobata (L.) Gray (Lepidoziaceae), *Judziewicz 11187* (WIS).

Calypogeia muelleriana (Schiffn.) Müll. Frib. (Calypogeiaceae), *Gunderson 661* (WIS).

Frullania asagrayana Mont. (Frullaniaceae), *Culberson 3507* (WIS).

Frullania riparia Lehm. (Frullaniaceae), *Gunderson 653* (WIS).

Marchantia polymorpha L. (Marchantiaceae), *Gunderson 651* (WIS).

Moerckia hibernica (Hook.) Gottsche (Pallaviciniaceae), *Gunderson 658* (WIS).

Mosses:

Brachythecium rivulare Schimp. (Brachytheciaceae), no collector or data (MICH).

Brotherella recurvans (Michx.) M. Fleisch. (Sematophyllaceae), *Culberson 1451* (WIS).

Dicranum flagellare Hedw. (Dicranaceae), *Culberson 1449* (WIS).

Entodon cladorrhizans (Hedw.) Müll. Hal. (Entodontaceae), *Hermann 28614* (DUKE).

Hedwigia ciliata (Hedw.) P. Beauv. (Hedwigiaceae), *Judziewicz 10829* (WIS).

Hylocomium splendens (Hedw.) Schimp. (Hylocomiaceae), *Judziewicz 11186* (WIS).

Lindbergia brachyptera (Mitt.) Kindb. (Leskeaceae), *Culberson 3687* (WIS).

Pohlia nutans (Hedw.) Lindb. (Bryaceae), *Hansen 3242* (MICH).

Polytrichum strictum Brid. (Polytrichaceae), *Gale s.n.* (WIS).

Sphagnum angustifolium (Warnst.) C.E.O. Jensen (Sphagnaceae), *Gale s.n.* (WIS).

Sphagnum fimbriatum Wilson (Sphagnaceae), *Hansen 3207* (NY).

Comparative diversity of the bryoflora of Butternut Pines

Our literature search enabled us to compile Table 1, in which we compare expected versus observed bryodiversity to obtain a crude "Diversity Quotient" (DQ) for each site, based on its size and the well-known species-area relationship (Mitchell and Ryan 2001). Upon log-transforming the data and fitting a regression line to it, using Social Science Statistics (2020), a species-area relationship for midwestern United States bryophytes was generated, encapsulated in the formula $S = 49 \times A^{0.109}$, where S is the number of species present and A is the area in acres of the tract. Based on this formula, Butternut Pines has a DQ of 1.52, meaning that it is 52% richer in bryophyte species than predicted by its size alone. The only other tract in the Midwest that is richer than Butternut Pines was Woodman Hollow State Preserve in Webster County, Iowa, with a DQ of 1.84. Woodman Hollow (Peck 1978) features a diverse mix of forested sandstone, limestone, and dolomite gorges and waterfalls that probably account for its exceptional bryodiversity. All other small (less than 100,000 acres) tracts in Table 1 have DQs ranging from 0.35 to 1.25.

DISCUSSION

The bryoflora of Butternut Pines is dynamic. The 2 ha (5 acre) Scotch pine plantation in the southwestern corner of the tract, planted in 1956, had a ground cover of 6.5% *Polytrichum piliferum* in 1977; this percentage declined to 0.8% in 2005 (Judziewicz 2010), and to just 0.08% in 2016 (Judziewicz and Zaborsky in prep.). With the decline of *Polytrichum piliferum* in the understory, the ground cover of the plantation is now dominated by eastern ground cedar (*Diphasiastrum digitatum* (A. Braun) Holub, Lycopodiaceae). Another declining species is *Climacium dendroides*, which was common in successional forests in 1994, but is much less common now; a similar but not as prominent decline was noted in *Pleurozium schreberi*. *Sphagnum russowii*, present as a tiny colony at the edge of a fen (Hawthorn Glen), was seen from 1978 to 1994, but has not been noted since.

Wisconsin has 412 species of mosses, 143 species of liverworts, and three species of hornworts (Rose 2019) for a total of 558 species of bryophytes, compared with about 2,600 vascular plant species (Online Virtual Flora of Wisconsin 2020). With 577 naturally-occurring species of vascular plants (Judziewicz 2004; Judziewicz and Zaborsky in prep.) and 111 bryophyte species, Butternut Pines has a total of 688 species of land plants (Embryophyta), which, as far as we have been able to ascertain in our search of the literature, is a record for a temperate zone tract of comparable size,

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This paper is dedicated to bryologist Frank D. Bowers (1936–2019), University of Wisconsin-Stevens Point biology professor from 1975 to 1997. We acknowledge the helpful comments of two

TABLE 1: Bryophyte floras and florulas of the midwestern United States, listing, for each, the number of recorded species, the predicted number of species, and the Diversity Quotient (the number of observed bryophyte species divided by the predicted number of species). The predicted number of species is derived from the species-area curve for bryophytes in the midwestern United States, S = 49 x A0.109, where S is the number of species present and A is the area in acres of the tract (see text for fuller explanation). The table is ordered by area size, from largest to smallest.

Site, County, State	Area (acres)	Moss species	Liverwort and hornwort species	Bryophyte species	Predicted number of bryophyte species	Diversity quotient	Reference
Wisconsin	35,000,000	412	146	558	331	1.69	Rose 2019
Bayfield County, Wisconsin	945,920	251	80	331	222	1.49	Rose 2019
Sauk County, Wisconsin	531,840	211	52	263	209	1.26	Rose 2019
Portage County, Wisconsin	526.720	180	12	192	209	0.92	Rose 2019
Linn County, Iowa	464,000	91	18	109	206	0.53	Drexler 1942
Door County, Wisconsin	308,480	181	38	219	197	1.11	Rose 2019
Red Lake Peatlands, Beltrami and Lake of the Woods Counties, Minnesota	300,000	68	17	85	196	0.43	Janssens and Glaser 1986
Isle Royale, Keweenaw County, Michigan	131,840	208	53	261	179	1.46	Thorpe and Povah 1935
Pictured Rocks National Lakeshore, Alger County, Michigan	71,397	138	38	176	168	1.05	Glime 2002
Kickapoo River Valley, Vernon County, Wisconsin	ca. 5,000	100	14	114	125	0.91	Cole et al. 1979
Sugar Island, Chippewa County, Michigan	3,000	115	33	148	118	1.25	Steere 1934
Summer Island, Delta County, Michigan	2,200	105	25	130	114	1.14	Miller and Halbert 1971
Loud Thunder Forest Preserve, Rock Island County, Illinois	1,621	35	3	38	110	0.35	Shershen et al. 2018
St. Martin Island, Delta County, Michigan	1,292	81	24	105	108	0.97	Freire et al. 2019
Kalamazoo Nature Center, Kalamazoo County, Michigan	1,100	44	11	55	106	0.52	Ehrle 2005
Amnicon Falls State Park, Douglas County, Wisconsin	ca. 200	81	n/a	n/a	n/a	n/a	Koch and Schroeder 1977
Bixby State Park, Clayton County, Iowa	ca. 185	93	12	105	77	1.21	Kleinman and Blisard 2018
Woodman Hollow State Preserve, Webster County, Iowa	64	117	25	142	74	1.84	Peck 1978
Butternut Pines, Oconto County, Wisconsin	40	91	20	111	73	1.52	This study
Sapa Bog, Ozaukee County, Wisconsin	12	52	n/a	n/a	n/a	n/a	Bowers 1991

anonymous reviewers. UW-Stevens Point undergraduate Trent Ress assisted in labelling the collections.

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DNA BARCODING OF MACROFUNGI FROM THE 2018 SMITH FORAY: NEW FUNGAL RECORDS FOR WISCONSIN AND THE UNITED STATES OF AMERICA

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ABSTRACT

For accurate evaluation of fungal conservation, modern biodiversity surveys based on vouchered specimens and DNA barcoding are needed to augment records of fungal distribution and phenology. Even relatively well studied and populated regions of the United States lack comprehensive information on fungal biodiversity, which hampers our ability to swiftly respond to fungal population decline due to habitat loss, climate change, or other anthropogenic stressors. During the 2018 Smith Foray in Dane County, Wisconsin, we vouchered and DNA barcoded 63 specimens of macrofungi. Three species constituted first records for the United States, and 14 additional species were reported for the first time from the state of Wisconsin. Furthermore, eight species were new reports just at the county level, and barcode data for two species represented first records in GenBank, the national public repository for genetic information. Twenty-four specimens were assigned informal placeholder names due to the lack of similar references in GenBank and are fertile ground for future taxonomic studies. While sequence-based identification requires caution due to inaccuracies in reference databases, the prevalence of multilocus genetic data in contemporary taxonomy facilitates global linkages in fungal distribution and increasingly traceable biodiversity assessments.
KEYWORDS: Dane County, fungal biodiversity inventory, mushrooms, North American Mycoflora Project, sequence-based identification

INTRODUCTION

Despite their enormous importance for global ecosystem functioning and as reservoirs of genetic resources, fungi are one of the most understudied groups of organisms, especially in the context of conservation (Hawksworth 2004; Heilmann-Clausen et al. 2014; Willis 2018). Mycologists estimate that the total number of fungi on Earth may exceed 5 million species, yet we have described only approximately 150,000, or about three percent of the estimated total (Blackwell 2011; Willis 2018). Many regions, including ones with a long history of profes-

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sional mycological activity, lack comprehensive data on fungal biodiversity (Haelewaters et al. 2018). Such knowledge gaps in local funga (Kuhar et al. 2018)—undescribed fungal biodiversity and poorly understood distributions and phenology—hamper our ability to assess and respond to population declines. Anthropogenic disturbances such as climate change, habitat destruction, and excess nitrogen deposition threaten the well-being of fungi and the ecosystems whose functioning depends on them (Mueller 2017; Andrew et al. 2018; van der Linde et al. 2018), thereby lending urgency to increased biodiversity surveys for the accurate evaluation of the conservation status of fungal species. High-quality vouchers of mushrooms, ideally paired with detailed photography and DNA barcode data, serve as evidence of reproducing populations of macrofungi and as benchmarks for future assessments of fungal range shifts and population declines (Andrew et al. 2018).

In this paper, we report on macrofungi that were vouchered and DNA barcoded from the 2018 A.H. Smith Lake States Foray (commonly known as the "Smith Foray") on October 4–7, 2018 near Mazomanie, Wisconsin. This was the 44th annual Smith Foray, which has been held each year since 1975 to honor the mycological accomplishments of Dr. Alexander Smith (1904–1986) (Thiers 1987) and to foster interactions among mycologists in the Great Lakes region. Past foray locations have included sites in Indiana, Illinois, Michigan, Minnesota, and Wisconsin (Mycological Society of America 2019). Attendees typically consist of professional mycologists from the upper Midwest and their students, as well as other amateur and professional scientists who are interested in fungi. This annual event is an opportunity to enhance our knowledge of macrofungal biodiversity from the Great Lakes states, and ultimately to contribute our understanding of the response of fungi to global change (Andrew et al. 2018), by augmenting records of occurrence, distribution, and phenology of local mushroom taxa.

MATERIALS AND METHODS

Study-site Description

Fungi were collected from four areas in Dane County, Wisconsin, during the 2018 Smith Foray (Figure 1)—Festge County Park, Mazomanie Bottoms State Natural Area, Mazomanie Oak Barrens State Natural Area, and Walking Iron County Park—as well as opportunistically from several other locations around Dane County. These locations exist on the eastern edge of the extensive Driftless Area, a region surrounding the upper Mississippi River in Wisconsin, Minnesota, Iowa, and Illinois. As indicated by a lack of glacial till, the Driftless region was never glaciated during the last Ice Age (Hobbs 1999). It is characterized by a topology of rolling hills that contrasts with an otherwise smooth Midwestern landscape. Special geological features and ecosystems such as algific talus slopes harbor unique and speciose funga (Hawksworth 2010; Thompson and Colbert 2020). A short description of each of the four primary collecting sites is as follows:

Festge County Park in Cross Plains (43.121744 N, –89.6829076 W): Mature *Carya* spp. (hickory) and *Quercus* spp. (oak) are the primary tree species here. The steep topography of Festge County Park is evidence of the unglaciated history of this region and provides an overlook of the Black Earth Creek Valley and Blue Mound State Park in the distance.

Mazomanie Bottoms State Natural Area in Mazomanie (43.219381 N, –89.818698 W): This site encompasses a large area of Wisconsin River floodplain forest. The forest is dominated by *Acer saccharinum* L. (silver maple), *Ulmus* spp. (elm), *Tilia americana* L. (American basswood), and *Fraxinus* spp. (ash) and, in addition, contains occasional individuals of *Quercus bicolor* Willd. (swamp

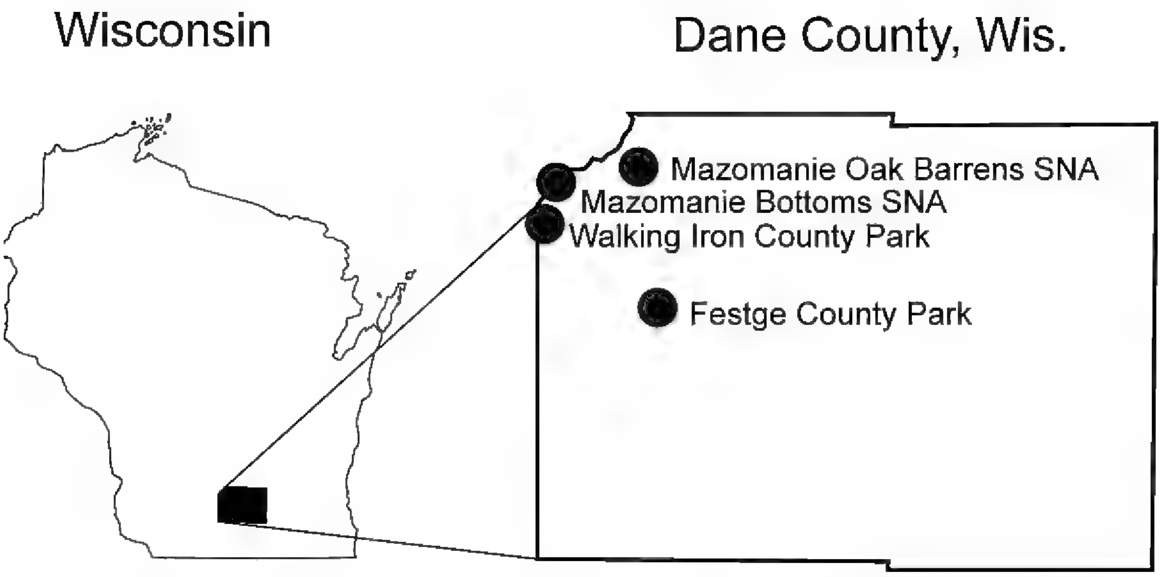

FIGURE 1. Map of the locations of the 2018 Smith Foray collection sites in Dane County, Wisconsin. "SNA" is an abbreviation for "State Natural Area".

white oak), *Populus deltoides* W. Bartram ex Marshall (eastern cottonwood), *Salix* spp. (willow), and *Betula nigra* L. (river birch). Elm mortality has resulted in canopy openings that support a dense understory of native and introduced shrubs. Periodic flooding results in sand bars, ephemeral pools, and river channels running through the forest.

Mazomanie Oak Barrens State Natural Area in Mazomanie (43.242305 N, –89.739786 W): This site is decidedly drier than the Mazomanie floodplain forests surrounding the Wisconsin River. Wisconsin's native cactus, *Opuntia cespitosa* Raf. (eastern prickly pear cactus) is abundant at Mazomanie Oak Barrens. Oak species such as *Quercus macrocarpa* Michx. (bur oak), *Quercus velutina* Lam. (black oak), and *Quercus alba* L. (white oak) interspersed with xeric prairie dominate in this dry, sandy environment.

Walking Iron County Park in Mazomanie (43.187734 N, –89.8246248 W): This park preserves a segment of the extensive prairie that extended from the bottoms area of the Wisconsin River to the surrounding oak savanna. Most of the park is sandy uplands covered by grasslands, including some unplowed, remnant prairie. The north area has a ridge that drops sharply down to Marsh Creek, one example of the many cool, spring-fed streams found in this part of the state.

Specimen Collection, Processing, and Vouchering

Macrofungal sporocarps were opportunistically collected at the foray locations by event participants and brought to a centralized processing area at Hoofbeat Ridge Camps. No effort was made to systematically cover a collecting location. Each specimen was tentatively identified by a local expert and recorded into a central database along with metadata such as collection location. Sixty-three mushrooms from the event were selected for DNA sequencing. These specimens were generally species that were new to the Smith Foray, of particular interest to the foray attendants, or that lacked reference sequence data in public repositories. Each specimen that was selected for DNA sequencing was assigned a collection number, photographed, and uploaded to iNaturalist (2020). The selected specimens were thoroughly dried in a dehydrator (Presto 06301) at 32°C. Dried specimens were deposited in the Kriebel Fungarium (PUL) at Purdue University and were digitally accessioned in the Mycology Collections data Portal (MyCoPortal 2020; Miller and Bates 2017).

Molecular Methods

Mushroom tissue was extracted from the interior flesh or gill tissue of fresh specimens at the foray processing center utilizing sterile forceps. The tissue was placed in 2.0 mL screw-top microcentrifuge tubes containing 600 µL of Promega Nuclei Lysis Solution (Promega Corp., Madison, Wisconsin). Each tube was labeled with the specimen's collection number and transported to the Aime Lab at Purdue University in West Lafayette, Indiana for DNA extraction and amplification. DNA extraction was accomplished by macerating the tissue using a sterile pestle, heating the solu-

tion at 65°C for 15 minutes, and centrifuging the contents of the tube at 21,000 g for three minutes. The supernatant was transferred to a 1.5 mL microcentrifuge tube, 200 µL of Promega Nuclei Lysis Solution was added, and the tube was then vortexed for 20 seconds. The solution was centrifuged again at 21,000 g for six minutes and the supernatant was added to a new, sterile, 1.5 mL microcentrifuge tube. 600 µL of 100% isopropanol was added to the supernatant to precipitate the DNA. The solution was centrifuged for one minute at 21,000 g and the supernatant was poured off, leaving the DNA pellet in the bottom of the tube. 600 µL of 70% ethanol was added to the tube, and the solution was centrifuged a final time for one minute at 21,000 g. The ethanol was poured out and the 1.5 mL microcentrifuge tube was placed upside down on a Kimwipe overnight. The following day, 30 µL of water was added to the tube, resulting in purified DNA for use in PCR amplification.

PCR amplifications of the internal transcribed spacer (ITS) ribosomal DNA (rDNA) region—the universal DNA barcode marker of fungi (Schoch et al. 2012)—were carried out using the ITS1F forward primer and the ITS4 reverse primer (White et al. 1990; Gardes and Bruns 1993). Each PCR reaction contained 12.5 µL Promega PCR Master Mix, 9 µL water, 1.25 µL forward primer, 1.25 µL reverse primer, and 1 µL DNA template for a total PCR volume of 25 µL. The following PCR protocol was used: (i) initial denaturation at 9C for one minute; (ii) 30 cycles of denaturation at 94°C for one minute, annealing at 51°C for one minute, and extension at 72°C for one minute; (iii) hold at 72°C for eight minutes. Electrophoresis with a 1% agarose gel was used to verify successful amplification. PCR amplicons were sent to Genewiz (Genewiz, Inc., Boston, Massachusetts, USA) for sequencing of both the forward and reverse DNA strands. The two reads were assembled using Sequencher 5.0.1 (Gene Codes Corp., Ann Arbor, Michigan) and the consensus sequence was deposited in GenBank (Clark et al. 2016). Raw DNA sequence data (trace files) are available at the 2018 Smith Foray MycoMap project (MycoMap 2018).

Species-level Determination

Identifications were made with a combination of macroscopic, microscopic, and/or ITS rDNA sequence analysis. For sequence-based identifications, consensus sequences were analyzed with the National Center for Biotechnology Information (NCBI) Basic Local Alignment Search Tool (BLAST®) (NCBI 2020) using the "megablast" option and excluding "uncultured/environmental sample sequences". Species-level assignments were made based on a minimum percent identity threshold of 98.5% and query coverage of 80%. Ambiguous nucleotides in the consensus sequence were regarded as correct if they matched the correct nucleotide in the reference alignment. Species-level identifications were not made if more than one specific epithet in the BLAST search corresponded with the cutoff values above. However, highly similar sequences from type specimens and UNITE species hypotheses took precedence when available (Nilsson et al. 2019). Species names were checked for synonymy and verified using MycoBank (Robert et al. 2013; MycoBank 2020). To facilitate the tracking of operational taxonomic units for future taxonomic research and biodiversity surveys, informal placeholder names were utilized. For specimens with ≥ 98.5% similarity to GenBank references with provisional specific epithets, those names were adopted here (e.g., taxa assigned a *nomen provisorum* by *Amanitaceae* expert Rod Tulloss); in addition, new placeholder labels (designated with the state initials for Wisconsin, WI) were generated for specimens for which no reference sequences had ≥ 98.5% similarity in GenBank (Table 1). These informal names serve to delineate likely taxa at the species level but do not necessarily imply that a given species is taxonomically novel; rather, additional research is required to obtain a sequence-supported identification for that specimen. Finally, to determine whether any identified specimens represented first records for Dane County, Wisconsin, or the United States, the currently known distribution of each species was checked in MyCoPortal (Miller and Bates 2017).

RESULTS

The identities and accession data of the 2018 Smith Foray macrofungi are listed in Table 1. Of the 63 specimens that were vouchered and sequenced, 35 (56%) were identified to officially described species, 24 (38%) were assigned

species-level informal names, and the remaining four specimens (6%) could only be identified to the genus level due to conflicting reference information. Taxonomically, these collections were spread across the phyla Ascomycota (five specimens) and Basidiomycota (58 specimens) and included 44 different genera. Twenty-five species represented new records for Dane County, 17 represented new records for the state of Wisconsin, and three represented new records for the United States. New records are indicated in Table 1.

DISCUSSION

A small portion of the total estimated number of fungal species are currently described, and even fewer have been evaluated for their conservation status (Hawksworth and Lücking 2017; Mueller 2017). More surveys of macrofungi are desperately needed to advance our understanding of fungal biodiversity and distribution, especially in the tropics (Aime and Brearley 2012). In turn, these data aid global change biologists in assessing fungal range shifts and population declines. By opportunistically sequencing specimens collected during the 2018 Smith Foray in Mazomanie, Wisconsin, we significantly expanded the known ranges of 17 fungal species, including three species that had not been previously reported from the United States, and provided novel genetic barcode data for 11 specimens of uncertain species-level taxonomic affinity (those with newly assigned "WI" informal placeholder labels) .

While great care is required in accurately interpreting sequencing results (Haelewaters et al. 2018; Hofstetter et al. 2019), modern biodiversity surveys of macrofungi using DNA barcoding routinely result in significant range expansions and uncover potentially novel species. For example, Haelewaters et al. (2018) discovered four new taxa, new fungal records for North America and Massachusetts, and a novel ecological interaction between a cheese mold (*Chrysosporium sulfureum* (Fiedl.) Oorschot & Samson) and woodlice (Crustacea: Malacostraca: Isopoda: Oniscidea) at a popular urban-island national park outside of Boston. Hofstetter et al. (2019) documented the polypore *Antrodiella stipitata* H.S. Yuan & Y.C. Dai for the first time in Europe and recorded four other macrofungal species for the first time in Switzerland, not to mention numerous very rare and indicator taxa. Together, these studies reveal the great paucity of information on fungal biogeography and the fact that fungi, even terrestrial macrofungi in populated areas, are an understudied reservoir of biodiversity. In the following paragraphs, we discuss several of the most interesting collections that were first records for the state of Wisconsin or for the entire United States.

Highlighted New Records for Wisconsin

Cortinarius dolabratus Fr. has been previously documented from Europe and North America, but in the United States it had only been collected in Alaska, California, and Washington (Liimatainen et al. 2017). Our collection (iNaturalist

TABLE 1. List of vouchered and DNA-barcoded fungal specimens from the 2018 Smith Foray in Mazomanie, Wisconsin. Each row corresponds to a single specimen and lists that specimen's determination as well as its accession numbers for iNaturalist (photos and metadata), MyCoPortal (fungarium information), and GenBank (ITS rDNA sequence). Informal placeholder names are enclosed by quotation marks; these names have either been propagated from other sources (in which case the name is followed by a citation) or are new labels from this study (all WI labels). The last column indicates whether a specimen was a new geographic record for just Dane County (DC), for Wisconsin and Dane County (WI), or for the United States, Wisconsin, and Dane County inclusive (US), or whether the ITS rDNA sequence that was generated for that specimen was the first reference for that species on GenBank; if the specimen was not novel in any of these regards, the column is marked with a hyphen.

Species	iNaturalist	MyCoPortal	GenBank	New Record
Agaricus kriegeri Kerrigan	17333117	6596294	MK573882	WI
Agaricus pallens L.A. Parra	17232000	6596228	MN989986	WI
Amanita solaniolens H.L. Stewart & Grund	17338999	6596241	MK573911	WI
Amanita sp. "longicuneus" (Tulloss and Rodríguez Caycedo 2020)	17333556	6596284	MK573886	-
Amanita sp. "texasorora" (Tulloss et al. 2020)	17231768	6596227	MK573879	-
Byssocorticium atrovirens (Fr.) Bondartsev & Singer	17333142	6596293	MN989989	-
Chalciporus piperatus (Bull.) Bataille	17338127	6596254	MK573906	DC
Clitocella sp. "WI-01"	17340579	6596231	MK573922	-
Clitocybe sp.	17340117	6596236	MK573913	-
Clitopilus abortivus Berk. & M.A. Curtis	17340459	6596234	MK573919	-
Collybia cookei (Bres.) J.D. Arnold	17231324	6596225	MK573873	DC
Coprinellus sp.	17334230	6596275	MK573891	-
Coprinellus sp. "IN-01" (Russell 2020)	17231181	6596224	MK573872	-
Coprinellus sp. "IN-01" (Russell 2020)	17339226	6596244	MK573918	-
Cortinarius dolabratus Fr. (Russell 2020)	17336721	6596258	MK573902	-
Cystoagaricus sp. "WI-01"	17332756	6596282	MK573876	-
Cystodermella sp. "IN-01" (Russell 2020)	17335122	6596272	MK573895	-
Cystodermella sp. "IN-01" (Russell 2020)	17339256	6596243	MK573917	-
Cystolepiota sp.	17334037	6596278	MK573889	-
Echinoderma sp. "IN-01" (Russell 2020)	17335043	6596283	MK573894	-
Entoloma psammophilohebes Vila & J. Fernández	17337073	6596255	MK573905	US
Flammula sp. "WI-01"	17338285	6596251	MK573909	-
Fuscopostia fragilis (Fr.) B.K. Cui, L.L. Shen & Y.C. Dai	17333313	6596290	MK573885	-
Galerina sp. "WI-01"	17339978	6596238	MK573914	-
Galerina triscopa (Fr.) Kühner	17338265	6596252	MK573908	WI
Gerronema subclavatum (Peck) Singer ex Redhead	17333993	6596279	MK573888	WI

Hygrocybe cantharellus (Schwein.) Murrill	17340623	6596230	MK573923	-
Hygrophorus sordidus Velen.	17333057	6596296	MK573880	DC
Hymenoscyphus fructigenus (Bull.) Gray	17332929	6596297	MK573877	-
Hymenoscyphus immutabilis (Fuckel) Dennis	17334099	6596277	MK573890	WI
Hypomyces sp. “WI-01”	17338188	6596253	MK573907	-
Inocybe ericetorum Vauras & Kokkonen	17323865	6596229	MK573874	US
Inocybe griseoscabrosa (Peck) Earle	17336824	6596256	MK573904	WI
Lactarius imperceptus Beardslee & Burl.	17339056	6596247	MK573912	DC
Lactarius sp. “IN-06” (Russell 2020)	17338937	6596250	MN989993	-
Lentinellus ursinus (Fr.) Kühner	17335268	6596266	MK573897	-
Lepiota castanea Quél.	17334272	6596273	MK573893	DC
Lepiota clypeolaria (Bull.) P. Kumm.	17336609	6596260	MK573900	DC
Lepiota umbrosa Morgan	17339931	6596239	MK573915	WI
Lepista sp.	17333187	6596292	MK573883	-
Limacella sp. “CMP0152” (Tulloss 2020)	17336802	6596257	MK573903	WI
Lycoperdon marginatum Vittad.	17231495	6596226	MK573878	-
Lycoperdon sp. “IN-01” (Russell 2020)	17340541	6596233	MN989996	-
Mycena griseoviridis A.H. Sm.	17336556	6596261	MK573899	GenBank
Mycena olida Bres.	17332707	6596281	MK573875	WI
Mycena sp. “WI-01”	17339784	6596242	MK573916	-
Mycena sp. “WI-02”	17332978	6596280	MN989988	-
Mycetinis sp. “WI-01”	17339146	6596245	MN989995	-
Neofavolus sp. “SAV-10” (Seelan Sathiya Seelan et al. 2015)	17333225	NA	MK573884	-
Neottiella vivida (Nyl.) Dennis	17333411	6596288	MN989990	WI
Otidea rainierensis Kanouse	17335858	6596263	MK573898	WI
Phleogena faginea (Fr. & Palmquist) Link	17333436	6596287	MN989991	GenBank
Pholiota highlandensis (Peck) Quadr. & Lunghini	17333602	6596286	MK573887	DC (WI, since 1967)
Pholiota highlandensis (Peck) Quadr. & Lunghini	17334245	6596274	MK573892	DC (WI, since 1967)
Ramaria sp. “WI-01”	17339094	6596246	MN989994	-
Rhodocollybia badiialba (Murrill) Lennox	17335179	6596271	MK573896	WI
Russula sp. “WI-01”	17340565	6596232	MK573921	-
Singerocybe adirondackensis (Peck) Zhu L. Yang & J. Qin	17336637	6596259	MK573901	DC
Tephrocybe sp. “WI-01”	17334189	6596276	MN989992	-
Tephrocybe sp. “WI-02”	17332892	6596285	MN989987	-
Tricholoma hemisulphureum (Kühner) A. Riva	17340511	6596237	MK573920	US
Tricholoma saponaceum (Fr.) P. Kumm.	17333116	6596295	MK573881	-

#17338950) is a 100.0% match to the epitype collection from Sweden (GenBank #KX964309) and thus is the first representative east of the Mississippi River. *Agaricus kriegeri* Kerrigan was described in 2016 from Pennsylvania (Kerrigan 2016). Our specimen (iNaturalist #17333117) is a 99.72% match (with 94% query coverage) to the type collection and is only the second vouchered record of this species aside from the Pennsylvania type collections. In regard to *Mycena olida* Bres., even though numerous collections of *M. olida* were made by Alexander Smith, an expert on *Mycena* and other genera of agarics, these collections were restricted to Michigan. Nomenclature databases do not agree on the current name of this taxon. Index Fungorum (Index Fungorum Partnership 2020) lists *Phloeomana minutula* (Sacc.) Redhead as the currently accepted name for *M. olida*, but MycoBank does not list them as synonyms. In naming our collection (iNaturalist #17332707), we follow the lead of MycoBank and Telfer et al. (2015), as our specimen is a 100% identity match with 100% query coverage to their specimen under this name (GenBank #KT695358). Lastly, we used microscopy to identity a specimen growing in moss at a xeric oak barren (iNaturalist #17333411) as *Neottiella vivida* (Nyl.) Dennis. Sequence data later showed a 99.28% match to GenBank accession #MF066095 from the Czech Republic, which was identified to the same species. Microscopic details for the Wisconsin specimen can be found at Mushroom Observer (2020).

New Records for the United States

In addition to being new records for Wisconsin, three species with vouchered collections and DNA sequence data are believed to be first records for the United States. *Entoloma psammophilohebes* Vila & J. Fernández was described in 2013 from a collection made in the Basque region of Spain. Our specimen (iNaturalist #17337073) is a 99.37% match (91% query cover) to the type collection (GenBank #JX454912). Additional specimens with a matching ITS region were also collected from Indiana a few weeks after the Wisconsin collection and again from Indiana in the fall of 2019. Images and metadata for these collections can be found at iNaturalist under accession #18030457 and #34805034, respectively. *Inocybe ericetorum* Vauras & Kokkonen was described in 2012 from Finland (Kokkonen and Vauras 2012) and had previously only been documented in eastern Canada. The ITS region of our specimen is a 99.09% match (86% query coverage) to the type collection (GenBank #NR_119994), expanding the range of this species into the Midwest. Finally, *Tricholoma hemisulphureum* (Kühner) A. Riva ex Bofelli was first described as *Tricholoma sulphureum* var. *hemisulphureum* Kühner in 1988 from France. Our Wisconsin specimen is a 99.84% match (87% query coverage) to a specimen with this name from Estonia, where the identity was determined to be appropriately applied for the morphological characters and sequence data present from the specimen (Heilmann-Clausen et al. 2017). There are two matching sequences from Florida which may represent the same species (GenBank #MF153041, #MF153084); however, they are currently listed under the name *Tricholoma sulphureum* in MyCoPortal.

CONCLUSION

Many of the new records reported in this study represent species that were described only recently. Indeed, the increasing prevalence of multilocus genetic data in taxonomic studies facilitates biodiversity assessments by augmenting the number of type specimens in reference databases. In turn, species that were thought to be isolated to confined geographic regions are discovered to exist across continents with high genetic similarity. In addition to the positively determined specimens from the 2018 Smith Foray, the 24 specimens that were assigned informal placeholder names constitute fertile avenues for future taxonomic investigations. They may represent previously described species for which no ITS barcode data exist in GenBank or novel species that await detailed analysis. We hope that informal placeholder names will make species associations traceable across time, allowing for the increased elucidation of the hidden biodiversity that is so prevalent in Wisconsin's macrofungi.

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EFFECTS OF BEAVER DISTURBANCE ON VEGETATION OF A PERMANENT PLOT IN THE HURON MOUNTAIN CLUB RESERVE

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ABSTRACT

Beavers (*Castor canadensis* and *C. fibre*) are significant modifiers of plant communities but studies are lacking on the indirect effects of beaver activity on the understory vegetation of non-riparian forests. Beaver cutting of saplings during 2011–2016 altered the vegetation in part of a permanent plot established in 2007 at the Huron Mountain Club Reserve in a *Pinus strobus–Picea glauca–Acer rubrum* stand with an understory of *Acer saccharum* saplings. Temporary ponding changed the community composition of another section of the plot. This study illustrates the importance of permanent plots, where before and after data are available to examine the effects of disturbances on succession. To examine beaver effects, a 0.34-ha study area that included a section cut by beaver, as well as an adjacent uncut section was established within the permanent plot. Within the study area, beaver felled 342 stems of 1-9 cm DBH (diameter at breast height), mostly *A. saccharum*. Diameter growth of saplings in the cut area was 1.8 times greater than in the uncut area. *Acer saccharum* or *Acer rubrum* sprouted from the majority of cut stumps and grew upward in spite of setbacks and forking from deer browsing. The *A. saccharum* sapling thicket that existed prior to cutting appeared to be reproducing itself, in contrast to other studies that reported that beaver cutting redirected succession from hardwoods to conifers. Frequencies of groundcover species were recorded annually during 2013-2019 in permanent belt transects, replicating data collected prior to beaver activity. Groundcover richness has increased in the cut area, along with an influx of *Rubus strigosus*, *Rubus parviflorus*, and other species associated with gaps. *Impatiens capensis* has colonized both cut and uncut areas, but its frequency has decreased since 2017. The most-abundant species prior to disturbance (*Dryopteris carthusiana*, *Maianthemum canadense*, *Trientalis borealis*) have retained high frequencies and should retain their dominance as the sapling thicket recovers. By contrast, in an area inundated during 2012-2015, these upland groundcover species have been replaced in dominance by dense *R. strigosus*. While succession of the cut area may show a resilience to beaver disturbance, that of the flooded area may be entering a recalcitrant understory phase, dominated by *R. strigosus* and resistant to tree establishment. Periodic beaver harvesting in the upland forest bordering Fisher Creek may be maintaining the *A. saccharum* sapling thicket in a cyclical understory succession.

KEYWORDS: Beaver, Huron Mountains, disturbance, succession, ground vegetation

INTRODUCTION

Beavers (*Castor canadensis* and *C. fibre*) are the only animals other than humans that are able to cut and fell trees, hence they can be a significant modifier of plant communities (Wright et al. 2002; Rosell et al. 2005; Nummi and Kuuluvainen 2013). Effects of beaver foraging on woody vegetation and succession have been investigated (Barnes and Dibble 1988; Johnston and Naiman 1990; Donkor and Fryxell 1999; Barnes and Mallik 2001). Donker and Fryxell (1999) and Barnes and Mallik (2001) concluded that beaver preference for hardwood species would favor succession toward conifers at their mixed study sites.

Studies are lacking on the effect of beaver cutting on vegetation of the forest floor. Beavers mostly forage on woody vegetation and aquatic herbs (Northcutt 1971; Allen 1983). Though beavers are known to ingest sedges and grasses (Allen 1983), the direct effects of beaver herbivory on upland groundcover are likely minimal. However, indirect effects caused by opening the subcanopy to increased light and by the disturbance created by cutting activity may be expected to alter ground species composition.

Long-term permanent plot studies are needed to examine empirical processes and test theoretical patterns of succession (Bakker et al. 1996; Johnson and Miyanshi 2008; Riege 2012). A permanent plot was established in 2007 in a late-successional *Pinus strobus–Picea glauca–Acer rubrum* forest at the Huron Mountain Club Reserve in Upper Michigan (referred to as the FCS plot in Riege 2011, 2013). During 2012–2016, beaver cutting of saplings opened up areas of a thick *Acer saccharum* subcanopy in the plot. With the availability of pre-disturbance data, I initiated a long-term study to investigate direct and indirect effects of beaver cutting on vegetation of the forest floor.

Part of the FCS permanent plot was flooded by shallow beaver ponding during 2012–2015. Upon the recession of the waters in 2016, I began to examine the effects on groundcover of this episode of flooding. Although changes in riparian vegetation in abandoned beaver ponds have been reported (Barnes and Mallik 2001; McMaster and McMaster 2001; Wright et al. 2002), research is lacking on changes in groundcover in an upland forest after temporary inundation. Hyvönen and Nummi (2008) investigated post-inundation changes in woody vegetation, but not ground herbs, in the uplands bordering abandoned ponds.

This paper addresses the questions: (1) how does beaver cutting affect understory vegetation in a mature mixed forest? (2) how does an episode of beaver ponding affect groundcover? (3) what are the implications of these beaver disturbances for future succession of the stand? Previous studies of succession after beaver disturbance used a chronosequence approach, comparing sites that differ in years since beaver abandonment (Barnes and Mallik 2001; McMaster and McMaster 2001; Hyvönen and Nummi 2008). This beaver-effects study applied a temporal approach, tracking changes over many years via replicated data in a permanent plot.

METHODS AND MATERIALS

Study area

The 2500-ha Huron Mountain Club Reserve in Upper Michigan contains extensive forests of old-growth mesic hemlock and hardwoods (Braun 1950; Woods 2000). During 2007–2008, I established two adjacent permanent plots totaling 2.4 ha by Fisher Creek in the reserve, which were described in Riege (2011, 2013). The 0.82-ha south plot (Fisher Creek South, or FCS) contained a *Pinus strobus–Picea glauca–Acer rubrum* stand with a thick sapling understory of *A. saccharum.* During October 2011, considerable flooding along Fisher Creek was noted and beaver cutting of saplings along its bank was evident, but no cutting was yet observed on the FCS plot. However, by May 2012, beaver cutting had created openings in the maple sapling thicket of FCS. A canal had been constructed that reached some 25 m into the plot. By September 2012, flooding inundated the south end of the FCS plot.

During 2013, I established a study area (N46.858°, W87.882°) of 0.34 ha within FCS to examine effects of beaver cutting on the vegetation. The study area included a 0.1-ha subplot (H1), which had

TABLE 1. The basal area in m2/ha of individual species and the totals in the Huron Mountain Club Reserve FCS plot in 2011 and 2016.

	2011	2016
Pinus strobus	30.4	28.8
Picea glauca	5.8	4.8
Acer rubrum	5.5	4.8
Acer saccharum	1.3	0.7
Tsuga canadensis	1.2	1.0
Betula alleghaniensis	0.9	0.9
Abies balsamea	0.5	0.1
Ostrya virginiana	0.0	0.0
Acer pensylvanicum	0.0	0.0
Totals	45.5	40.8

been embedded in FCS to monitor the growth and survival of small saplings. The study area boundaries were delineated to include all area within 10 m of previously established transect lines in FCS that were not flooded. Areas of beaver cutting were distinct from uncut areas. For analysis of beaver effects, the study area was divided into a cut area (0.20 ha), where beaver had felled saplings, and an uncut area (0.14 ha). The cut area was delineated to extend 1 m beyond the outermost line of cut stems.

By 2016, waters had receded from the south end of FCS. Changes in the permanent transects within the flooded zone were added to this project to examine effects of temporary beaver ponding on the vegetation. Most trees (stems ≥ 10 cm DBH) died in the flooded area by 2016. Table 1 illustrates a decrease in basal area of tree species in the FCS plot from 2011 to 2016. (Beaver effects on tree composition of the plot are not included in this paper.)

Field Methods

Saplings are defined as all trees with stems between 1.0 and 10.0 cm DBH. For purposes of this study, these are divided into small saplings (stems 1.0–4.9 cm DBH) and large saplings (stems 5–9.9 cm DBH). During August 2013, all small saplings that occurred within 10 m from the transect lines were mapped and diameters measured, as were all cut stems ≥ 1 cm diameter at 15 cm in height. Diameter measurements were at 1-cm scale, rounding down. Large saplings had already been measured in 2011. Each autumn thereafter, all new cuts in the study plot were recorded. During autumn 2018, I remeasured diameters of all saplings from 1 to 9 cm DBH in the beaver study area.

In order to calculate a regression formula to estimate the DBH of cut stems prior to cutting (with the exception of cut stems in subplot H1 where DBH had been measured in 2011), nineteen saplings were measured in 2013 at both 15 cm height and at DBH (i.e., at about 1.4 m height). The resultant formula of DBH = (0.95 * base diameter) – 0.36 cm was used to estimate DBH prior to cutting. Using the formula, stem bases that measured 5–9 cm in diameter were adjusted for DBH by subtracting 1 cm, since diameters were recorded in whole numbers in the plots. A sample of 19 stems was considered sufficient to make adjustments at this 1-cm scale.

Beginning in July 2016, the tallest living height was measured on sprouts from the cut stumps that were within 1 m from the transect midlines. During 2016–2018, these measurements were an informal addition to the ground sampling, and some sprouts were missed. During July 2019, in a separate dedicated survey, all cut stumps within 1.5 m of the midlines were tallied, and all sprouts were mapped and their heights measured.

Beginning in summer 2013, then annually through 2019, the presence by species of tree seedlings, shrubs, and herbs within the study area was recorded in continuous transects of 2 × 2-m quadrats (that is, all species occurring within 1 m of a tape laid along the transect lines were recorded). Tree seedlings were defined as stems less than 1 cm DBH (diameter at breast height). This replicated the sampling protocol of 2011 for these permanent plot transects, which had been carried out prior to the beaver activity. A total of 96 quadrats were sampled within the beaver study area: 65 in areas of cutting, 31 in uncut areas.

As part of the 2016 remeasurement protocol, species composition of groundcover was recorded in the 32 south FCS transects that were inundated for most of 2012–2015, but in which the waters had receded by 2016. Thereafter, the groundcover in the 32 quadrats was sampled annually through 2019.

Analysis

Diameter growth rates of saplings within the study area and within the subplot H1 were compared by the nonparametric Wilcoxon rank sum test, as the rates were not normally distributed. The Chi-square test was used to examine any beaver preference for size of sapling to cut. Statistical tests were considered significant if $p < 0.05$.

Quadrat species richness is defined as the number of different species found in a quadrat. The species listed in this paper are only those found in the quadrats and therefore do not represent a complete flora of the study area. Individuals in the genera *Carex*, *Juncus*, and *Solidago* were not identified to species. However, it was evident when more than one *Carex* species was present in a quadrat. Thus, for purposes of determining species richness, the number of *Carex* species in each quadrat was recorded. Nomenclature follows Voss and Reznicek (2012) for seed plants and MICHIGAN FLORA ONLINE (2011) for pteridophytes.

With the groundcover sample quadrats, the two-sample *t*-test was applied to determine if mean quadrat species richness differed between the cut and uncut areas during each year of the study. With the 32 inundated quadrats, species richness before and after flooding was also examined by the paired *t*-test. Statistix 9.0. software was used for statistical analyses.

RESULTS

Effects of beaver cutting on saplings

By October 2016, beavers had cut 342 saplings of 1–9 cm DBH in the 0.34-ha study area. No new cuts were found after 2016. Most of the cutting (267 stems) had occurred by September 2013. No stems greater than 9 cm DBH were felled. Beavers downed 82% of the saplings in the 0.20-ha cut area, thereby decreasing the density from 2090 to 380 saplings/ha. Beaver cut 85% of the saplings 1–5 cm DBH ($n = 398$), but only 23% of saplings 6–9 cm DBH ($n = 20$). However, no significant difference was found in beaver preference for available stem sizes by the Chi-square test ($\chi^2 = 12.2$, $p = 0.14$, $df = 8$). From pre-cut stem maps or sprouts from stumps, I was able to identify 68% of the cuts to species; of these 94% were *Acer saccharum*. Also identified among the cuts were *A. rubrum* ($n = 10$), *A. pensylvanicum* ($n = 2$), and *Picea glauca* ($n = 1$), which was consistent with their small numbers on the plot.

Since the beaver disturbance, the diameter growth of saplings has been greater in cut than uncut areas. Within subplot H1, which was measured in 2011 prior to beaver activity, growth of all saplings from 2011 to 2018 averaged 0.91 cm versus 0.50 cm in the uncut area ($p = 0.03$, Wilcoxon rank sum test). The small saplings in the study area outside of H1 were first measured in 2013. Their 5-year diameter growth rate was also greater in cut than in uncut areas (0.63 cm versus 0.35 cm), but not at a significant level ($p = 0.15$, Wilcoxon rank sum test), although their mean annual growth rate (ca. 0.06 cm/year) was similar to that in H1. Within the entire beaver study area, diameter growth of large saplings from 2011 to 2018 was also greater in cut than in uncut areas (mean of 1.62 cm versus 0.92 cm, $p = 0.04$, Wilcoxon rank sum test).

FIGURE 1. Beaver-cut opening in a thicket of maple saplings. June 2013. Photo by Dennis Riege.

FIGURE 2. The same view as Figure 1: Maple saplings reclaiming the opening. September 2019. Photo by Keith Nelson.

Throughout the cut area, maple seedlings have sprouted from the stumps. The *Acer saccharum* sapling thicket that was felled appeared to be reproducing itself (Figures 1 and 2). During July 2019, a total of 64 cut stumps were found within 1.5 m from the transect midlines. Maple sprouts (40 *Acer saccharum*, 3 *Acer rubrum*) have emerged from 67% of the stumps. Although the median height of these sprouted seedlings was 140 cm, eleven *A. saccharum* sprouts have grown to exceed 200 cm in height by 2019, which is likely above the deer browse zone. The tallest *A. saccharum* sprout in the transects reached 400 cm in seven years of growth. However, most spouts have experienced browse back during this time. Of 15 sprouts with four years of measurements, ten have experienced at least one annual decrease in height (Figure 3), with sign of browsing by deer. This has resulted in multi-branched growth with forking of the many stems sprouting from the cut stumps (Figure 4). Although some were repeatedly browsed, only two of the 43 monitored sprouts were noted to have died by 2019 (Figure 5).

Effects of beaver cutting on the groundlayer

The groundlayer species that were dominant in 2011 maintained high frequencies through 2019, in both cut and uncut areas (Table 2: *Dryopteris carthusiana*, *Maianthemum canadense*, *Trientalis borealis*, seedlings of *Acer saccharum* and *Acer rubrum*). The greatest change in the vegetation was the invasion of the annual *Impatiens capensis*, a native species that colonized both the cut and the uncut areas (Table 2; Figure 6). In 2014, *Impatiens capensis* was not recorded in the quadrats. In 2015 it was widespread in the cut (32% of quadrats) and uncut areas (26%). After a maximum of 52% in 2017, *Impatiens capensis* frequencies have decreased (Figure 5). *Rubus strigosus* and *Rubus parviflorus*, species that associate with gaps, have increased from 2–5% to 20–29% frequency in the cut areas. Several species appeared in the cut-area quadrats for the first time in 2014 (e.g., *Scutellaria laterifolia, Scuttelaria galericulata, Fallopia convolvulus, Circaea alpina, Potentilla norvegica, Ribes glandulosum*), although the latter three were absent by 2019. Two forbs, *Viola blanda* and *Osmorhiza claytonii*, which were common prior to cutting, were absent from the uncut area by 2014 and from the cut area by 2017 (Figure 6). *Acer saccharum* and *Acer rubrum* dominated the tree seedlings in the quadrats (Table 2). Seedlings of the two most dominant trees in FCS, *Pinus strobus* and *Picea glauca,* were rare. The cut areas exhibited greater tree seedling richness, including four species (*Alnus incana*, *Fraxinus nigra*, *Prunus serotina*, *Quercus rubra*) that were not found in the uncut quadrats.

Effects of temporary beaver ponding on the groundlayer

Whereas dominant ground species in the main study area maintained high frequencies after beaver cutting, the ground vegetation in the flood zone quadrats shifted dramatically from upland forest species (e.g., *Dryopteris carthusiana, Maianthemum canadense, Acer saccharum* seedlings) in 2011 to riparian and gap species (e.g., *Rubus strigosus, Impatiens capensis, Carex* spp.) in 2016–

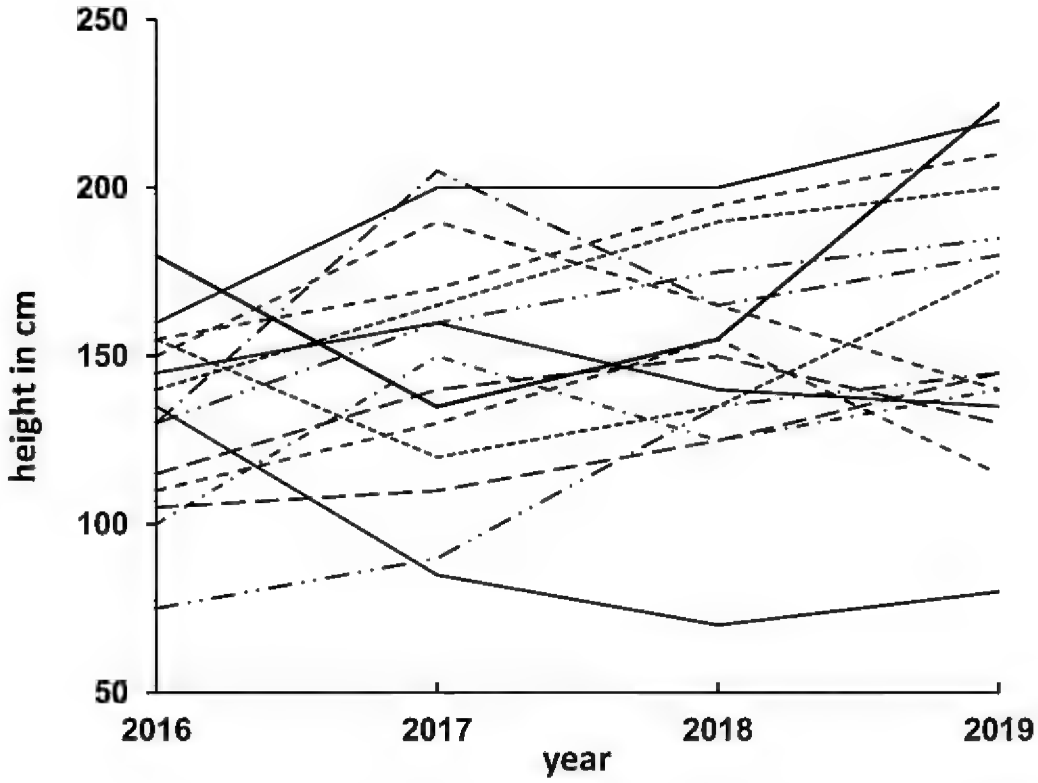

FIGURE 3. Changes in height of 15 maple seedlings from 2016 to 2019 that had sprouted from stumps cut by beaver in 2013 or 2014, showing a general upward trend but with setbacks due to browsing. Each line represents one seedling.

FIGURE 4. A sprout of *Acer rubrum* from a cut stump, illustrating forking of the multiple stems. Photo by Dennis Riege.

FIGURE 5. A sprout of *Acer rubrum* from a cut stump that died in 2019 after much browsing. Photo by Keith Nelson.

2019 (Table 3). Almost all trees and saplings died after inundation, creating a large gap. *Impatiens capensis* reached 100% frequency in 2017, but has since decreased, paralleling its trend in the main study area. As in the cut areas, *Rubus strigosus* has increased, although more extensively in the flood zone, to 94% frequency in 2019. A dense thicket dominated by *R. strigosus* has grown to ca. 1.4 m in height (Figure 7). Many species that were not observed in 2011 appeared after the waters receded, most notably *Calamagrostis canadensis*, *Fallopia convolvulus,* and *Scutellaria galericulata* (Table 3).

Effects of beaver disturbance on species richness

Mean groundlayer species richness in the cut area increased from 5.3 to 6.3 species per 4 m^2 quadrat from 2011 to 2019, while it decreased in the uncut area from 5.9 to 5.3. Since 2015, mean richness has been significantly greater in the cut area (Table 4). Species richness declined in the flood zone from 5.2 species per quadrat in 2011 to 4.4 in 2016 after flooding, but not significantly ($p = 0.10$,

TABLE 2. Frequencies of ground species in the cut area and the uncut area in selected years, as measured by the percentage of quadrats in each area in which each species is present. The 2011 column reflects data prior to beaver cutting. Species with all zero values were present in years other than listed.

	Cut Area			Uncut Area		
	2011	2016	2019	2011	2016	2019
Tree Seedlings						
Abies balsamea L.	3	0	0	3	0	0
Acer pensylvanicum L.	14	14	15	13	16	19
Acer rubrum L.	20	48	60	39	42	84
Acer saccharum Marshall	84	71	75	80	55	65
Alnus incana (L.) Moench	0	2	0	0	0	6
Betula alleghaniensis Britton	2	6	12	0	0	0
Fraxinus nigra Marshall	0	0	2	0	0	0
Ostrya virginiana (Mill) K. Koch	9	9	3	13	13	6
Picea glauca (Moench) Voss	5	6	6	0	0	0
Pinus strobus L.	5	0	2	0	0	0
Prunus virginiana L.	0	3	2	0	3	0
Prunus serotina Ehrh.	0	0	0	0	0	0
Quercus rubra L.	0	3	3	0	0	6
Tsuga canadensis L.	3	8	2	3	0	0
Herbs and Shrubs						
Aralia nudicaulis L.	22	28	35	23	16	23
Brachyelytrum aristosum Michx	12	11	17	19	16	13
Carex spp	26	39	35	16	6	19
Circaea alpina L.	0	0	0	0	0	0
Clintonia borealis (Aiton) Raf.	11	0	0	19	6	6
Coptis trifolia (L.) Salisb.	3	6	3	10	6	6
Cornus canadensis L.	3	6	6	13	6	13
Corylus cornuta Marshall	6	5	6	0	0	0
Dryopteris carthusiana (Vill.) H. P. Fuchs	97	95	94	94	84	90
Eurybia macrophylla (L.) Cass	0	0	0	0	0	0
Fallopia convolvulus (L.) A. Love	0	6	2	0	0	0
Galium triflorum Michx.	5	2	0	0	0	0
Huperzia lucidula (Michx.) R. Trevis	6	0	2	0	0	0
Impatiens capensis Meerb.	0	35	18	0	36	23
Juncus spp.	0	3	2	0	0	0
Lonicera canadensis Marshall	9	6	5	16	16	16
Maianthemum canadense Desf.	78	74	78	87	74	74
Oryzopsis asperifolia Michx.	6	8	5	6	3	0
Osmorhiza claytonii (Mich.) C. B. Clarke	11	0	0	23	0	0
Polygonatum pubescens (Willd.) Pursh.	0	3	2	0	0	0
Potentilla norvegica L.	0	2	0	0	0	0
Pteridium aquilinum (L.) Kuhn	5	6	3	0	0	0
Pyrola elliptica Nutt.	0	0	2	0	0	0
Ribes glandulosum Grauer	0	0	0	0	0	0
Ribes lacustre (Pers.) Poir.	2	0	0	0	0	0
Rubus strigosus Michx,	2	20	29	0	0	0
Rubus parviflorus Nutt.	5	20	20	0	0	0
Scutellaria galericulata L.	0	2	2	0	0	2
Scutellaria lateriflora L.	0	2	2	0	0	0
Streptopus lanceolatus (Aiton) Reveal	6	0	0	16	0	0
Symphyotrichum lanceolatus Willd.	0	2	0	0	0	0
Trientalis borealis Raf.	58	59	74	65	55	58
Trillium cernuum L.	2	3	2	3	0	3
Vaccinium angustifolium Aiton	0	2	2	0	0	0
Veronica officinalis L.	0	0	0	0	0	0
Viola blanda Willd.	28	6	0	23	0	0

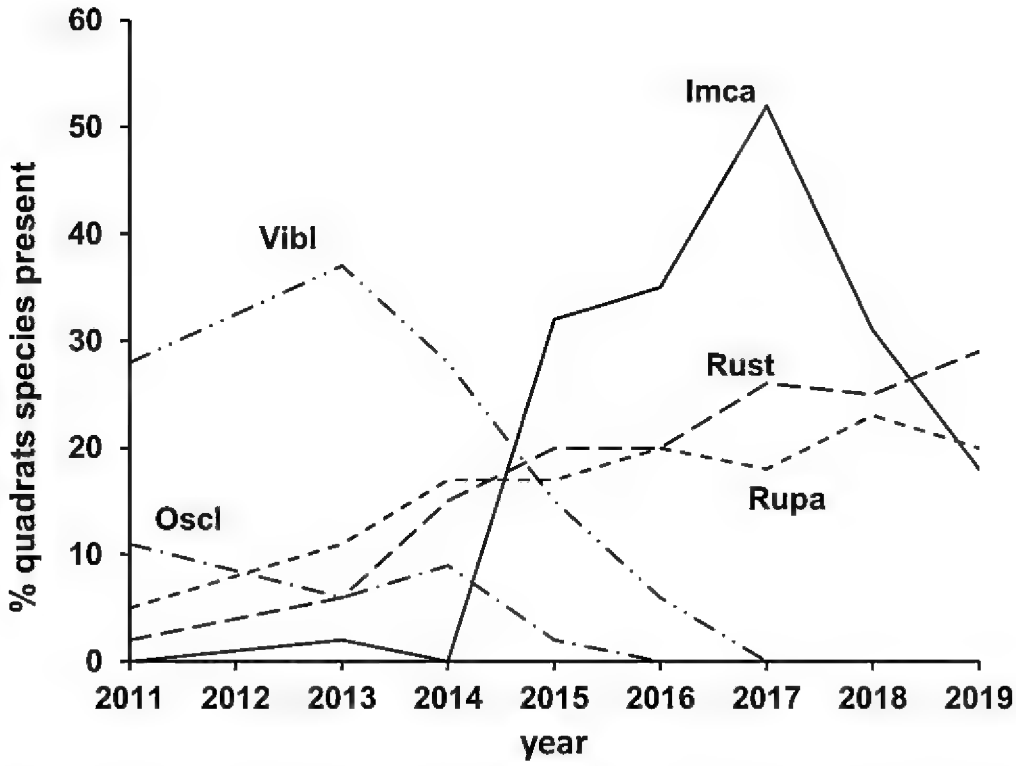

FIGURE 6. Frequencies over time of five species within the beaver-cut area as measured by the percentage of quadrats in which each species is present. The 2011 data was recorded prior to beaver cutting. Vibl = *Viola blanda*; Oscl = *Osmorhiza claytonii*; Imca = *Impatiens capensis*; Rust = *Rubus strigosus*; Rupa = *Rubus parviflorus*.

df = 31, paired *t*-test). However, by 2017 mean richness per quadrat was similar to that in 2011 (Table 4), although species composition had radically changed (Table 3).

DISCUSSION

Acer saccharum sprouts and seedlings are beginning to grow rapidly in the cut areas, especially from the remnant stumps. By this trajectory, *A. saccharum* will be the most successful species in reclaiming the clearings created by beaver. The beaver disturbance will likely have the effect of a cyclical succession in the understory back to an *A. saccharum* sapling thicket similar to the one that existed in 2011. This pattern contrasts with studies that concluded that beaver preference for hardwood species would alter succession toward conifers (Donkor and Fryxell 1999; Barnes and Mallik 2001). Although conifer species accounted for 85% of the basal area of the FCS stand (Table 1), conifer saplings (Riege 2011) and seedlings (Tables 2 and 3) were very rare, perhaps due to the dense shade of the thicket. Hence, *A. saccharum* should face little competition from conifers in the understory.

Similar to this study, Jacobs (1969) found considerable episodic height reduction and forking in deer-browsed *Acer saccharum* seedlings. In spite of this browse back, he reported that seedlings in favorable, open areas grew out of

TABLE 3. Frequencies of ground species in the transects that were inundated for most of 2012–2015, as measured by the percentage of quadrats in which each species is present. The 2011 column reflects data prior to inundation, and the 2016 and 2019 columns reflect post-flooding data. Species that were present in 2017 or 2018 are listed with all zero values for 2017 and 2018.

	2011	2016	2019
Tree Seedlings			
Abies balsamea	0	6	0
Acer pensylvanicum	13	0	0
Acer rubrum	19	9	25
Acer saccharum	75	13	16
Alnus incana	0	0	6
Betula alleghaniensis	0	0	3
Ostrya virginiana	3	0	0
Picea glauca	0	0	13
Prunus virginiana	0	0	0
Quercus rubra	0	0	3
Herbs and Shrubs			
Aralia nudicaulis	19	3	6
Athyrium felix-femina (L.) Roth	0	0	0
Brachyelytrum aristosum	13	3	19
Calamagrostis canadensis (Michx.) P. Beauv.	0	19	25
Carex spp	47	88	69
Chelone glabra L.	0	0	6
Cirsium muticum Michx.	0	3	0
Dryopteris carthusiana	88	38	63
Eqisetum sylvaticum L.	3	3	3
Eurybia macrophyllum	6	0	0
Fallopia convolvulus	0	9	25
Galium triflorum	6	3	3
Impatiens capensis	0	94	50
Iris versicolor L.	0	3	3
Juncus spp.	0	19	6
Lonicera canadensis	6	0	0
Maianthemum canadense	84	16	16
Onoclea sensibilis L.	6	9	9
Oryzopsis asperifolia	3	0	0
Osmunda cinnamomea (L.) C. Presl	0	0	3
Osmorhiza claytonii	38	0	0
Potentilla norvegica	0	3	0
Pteridium aquilinum	3	0	0
Pyrola elliptica	3	0	0
Rubus strigosus	0	63	91
Rubus parviflorus	6	3	3
Sambucus racemosa L.	3	0	0
Scutellaria galericulata	0	31	16
Solidago spp.	0	6	3
Trientalis borealis	44	9	19
Trillium cernuum	3	0	0
Verbascum thaspus L.	0	0	0
Viola blanda	16	0	0
Viola cucullata Aiton	13	0	0

FIGURE 7. Dense *Rubus strigosus* thicket in 2018 that developed in an area inundated during 2012–2015. The ground cover was dominated by upland herbs in 2011 prior to flooding. Photo by Keith Nelson.

reach of deer. This also seems to be the case at Fisher Creek, where deer may slow but not stop sapling growth in *A. saccharum*. Fei and Steiner (2009) noted that *A. rubrum* can regain the growing space it occupied in seven years after harvesting by stump sprouting alone. *Acer saccharum* is a less prolific sprouter than *Acer rubrum* (Solomon and Blum 1967), but appears to be well on its way to regaining its space at Fisher Creek.

Diameter growth of saplings in the cut area was 1.8 times greater than the

TABLE 4. Species richness (mean number of species per quadrat) ± standard error per year of ground plants in the cut, uncut, and flooded areas. The 2011 data was recorded prior to beaver activity. The flooded area was inundated during the period 2012–2015. A single asterisk (*) indicates data for which $p < 0.05$; a double asterisk (**) indicates data for which $p < 0.01$, indicating that the cut area differs from the uncut area by the two sample *t*-test.

Year	Uncut	Cut	Flooded
2011	5.9 ± 0.3	5.3 ± 0.4	5.2 ± 0.3
2013	4.9 ± 0.5	5.0 ± 0.3	
2014	5.0 ± 0.4	5.9 ± 0.3	
2015	4.8 ± 0.4	6.8 ± 0.4**	
2016	4.6 ± 0.4	6.1 ± 0.3 **	4.4 ± 0.3
2017	4.6 ± 0.4	5.8 ± 0.3 *	5.0 ± 0.3
2018	4.6 ± 0.4	5.9 ± 0.3 **	5.0 ± 0.3

uncut area. The uncut area remained shaded by a dense *A. saccharum* sapling understory. The cut area also was closer to the open corridor of Fisher Creek, further increasing light availability. The increased growth rate will facilitate the reproduction of the *A. saccharum* sapling thicket in the cut area. This leads me to speculate that past episodes of beaver cutting may have assisted in limiting *A. saccharum* to a dense subcanopy under the *Pinus strobus–Picea glauca–Acer rubrum* forest. McGinley and Whitham (1985) reported that selective beaver foraging on *Populus fremontii* kept it in a perpetual juvenile condition.

Most stems cut in this study were 2–5 cm DBH, and the largest was 9 cm DBH. Raffel et al. (2009) found a preference for 2–6 cm DBH stems, and that trees greater than 9 cm DBH were avoided by beavers. Beaver are known to fell much larger trunks. Donkor and Fryxell (1999) reported an average cut size of 15 cm DBH in lowland boreal forests. Johnston and Naiman (1990) found means of 14 cm and 10 cm at two sites, with a maximum cut of 43.5 cm DBH. When establishing at Fisher Creek in 2011, beaver encountered an abundance of small saplings. The overwhelming abundance of small *Acer saccharum* saplings limited size and species choice. Donkor and Fryxell (1999) did note that *A. saccharum* and *Acer rubrum* are preferred species.

The retention of high frequencies of the dominant species (Table 2) suggests resilience of the groundlayer community at Fisher Creek to disturbance by beaver cutting. *Rubus strigosus* and *Rubus parviflorus* have increased with the opening of the *A. saccharum* sapling thicket, but will likely decrease as the saplings reproduce shady cover. Donoso and Nyland (2006) found that *R. strigosus* abundance declines in clearcuts after about 5 years, as trees grow above the raspberry layer. This especially occurs in stands with advance regeneration, which may be the case with the stump spouting at Fisher Creek. Archambault et al. (1998) and Donoso and Nyland (2006) reported that most individuals of *R. strigosus* die within 10 years after logging.

Many species that first appeared in the cut-area quadrats in 2014 and 2015 (e.g., *Impatiens capensis*, *Ribes glandulosum*, *Scutellaria laterifolia*, *S. galericulata, Potentilla norvegica*, *Fallopia convolvulus*, *Circaea alpina*) are generally associated with moist, streambank, or disturbed habitats (Curtis 1959; Chadde 2013). With the exception of *I. capensis*, these species were rare and might be expected to decline with closure of the sapling subcanopy. *Impatiens capensis* is an annual plant that is able to germinate early in the spring in disturbed riparian areas and develop a dense population with a continuous canopy that exerts habitat dominance over the herbaceous layer (Winsor 1983). Early germination allows it to persist many years after a disturbance, although its range was decreasing five years after beaver cutting at Fisher Creek. Interestingly, *Impatiens capensis* colonized the uncut area at a similar rate as it did in the cut area (Table 3). Most of its invasion of the uncut area occurred in a heavily shaded sapling thicket with low ground cover. *Impatiens capensis* may well persist in the uncut areas longer, as it is facing dense competitive growth in the cut area, particularly by the *Rubus* shrubs. The forest herbs *Viola blanda* and *Osmorhiza claytonii* exhibited the greatest decrease, with neither species noted in cut or uncut quadrats after 2017 (Table 3). This may not be related to beaver disturbance, as both species also declined at other Huron Mountain Reserve plots in 2016 (Riege, un-

published data). Wiegmann and Waller (2006) reported both species as “losers” in 50 years of change in regional forests and believed deer herbivory a key factor. Shelton et al. (2014) reported that deer reduced abundance of *O. claytonii.*

While composition of the groundlayer in the main study area suggests resilience after beaver disturbance, vegetation in the flooded zone has been radically altered. Almost all trees have died. By 2019, dense *Rubus strigosus* filled the opened area (Figure 7). Donoso and Nyland (2006) reviewed examples where *R. strigosus* inhibited tree establishment beyond 15 years, in sites that were poorly drained or lacked advance regeneration. In their review of 125 studies, Royo and Carson (2006) included *Rubus* spp. among plants that can form what they termed a “recalcitrant understory layer” that can alter the rate or direction of succession.

Studies of succession post-inundation on non-riparian forests are rare. Hyvönen and Nummi (2008) reported that deciduous trees may be favored over conifers in this environment after beaver flooding. Terwilliger and Pastor (1999) found that flooding may kill the ectomycorrhizae necessary for conifer seedling establishment. *Acer saccharum*, *Acer rubrum*, and *Picea glauca* seedlings were present in the flood zone quadrats at Fisher Creek in 2019 (Table 3) but were small in size and numbers—far from an advance regeneration. Whether tree seedlings can develop through a potential recalcitrant *R. strigosus* layer is an open question. I suspect that the flooded area of FCS will not return to a *Pinus strobus–Picea glauca–A. rubrum* stand with an *A. saccharum* subcanopy, unless perhaps if undisturbed for several decades.

Groundlayer species richness in the cut area at Fisher Creek has increased as expected with colonization of gap species. Continuation of this study will allow testing of a hypothesis that species richness will peak and then decrease in the cut area as the *A. saccharum* sapling subcanopy redevelops and inhibits shade-intolerant species. This result would be in accord with the intermediate disturbance hypothesis (Connell 1978), which proposes that diversity increases to a maximum following a disturbance then declines.

This study illustrates the value of long-term permanent plots, where vegetation data are collected before and tracked after a disturbance. Forests are subject to many disturbances (e.g., disease, species invasions, wind-throw, climate change) that influence succession. Long-term plots in place prior to disturbance events provide invaluable opportunities for a cause-and-effect examination of vegetation dynamics (Bakker et al. 1996). Continuation of this project will test hypotheses that the trajectory of the beaver-cut area will trend to reproduction of pre-existing vegetation, while that of the beaver-flood area will stall in a multi-decadal recalcitrant understory layer.

ACKNOWLEDGMENTS

The Huron Mountain Wildlife Foundation has generously supported my research at the Huron Mountain Club Reserve. I especially thank its director, Kerry Woods, for advice from the start of my long-term studies. The Hanes Trust and the Michigan Botanical Foundation have been instrumental in providing funds to continue this beaver-effects study. Keith Nelson, Paul Baumann, Barry Rosett, and Alison Paulson assisted in the field data collection over the years. Thanks are due to Michael Rotter, Bil Alverson, Katie Frerker, Sarah Johnson, and Don Waller for help in species identifica-

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NOTEWORTHY COLLECTION

DISCOVERY OF A POPULATION OF STATE ENDANGERED *TRILLIUM ERECTUM* L. (MELANTHIACEAE) IN WEST CENTRAL ILLINOIS

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Significance of the report. This population extends the distribution of this species in Illinois 130 km to the south and adds a fourth Illinois county to the list of known sites for this state endangered plant in Illinois (Herkert 1991, Illinois Natural Heritage Database 2018). The species also appears to be unrecorded in the nearest adjacent states, Wisconsin, Iowa and Missouri (USDA Plants Database 2019).

Previous knowledge. *Trillium erectum* L., Purple, Red, or Ill-scented Trillium, is a perennial herb that is widespread in northeastern North America from southern Ontario to Nova Scotia and, in the Appalachians, as far south as northern Georgia (Case and Case 1997, USDA NRCS 2018). In the midwestern US, it occurs in eastern Ohio, in scattered locations in Michigan, and in at least four counties in Indiana (Dolan and Moore 2019, USDA NCRS 2019). In Illinois, it is state listed as an endangered species (Illinois Endangered Species Protection Board 2015). The Illinois Natural Heritage Database (2018) lists occurrences in three counties: Lake and McHenry Counties in the northeastern corner of the state and Carroll County in the northwest. There are two occurrences in the database for each of Lake and McHenry Counties and a single occurrence for Carroll County.

Discussion. This population of *Trillium erectum* was first noted in 2016 when a few plants were observed; in 2018 more extensive searching in the same location revealed over 100 stems. The plants were concentrated near the sloping banks of a small stream in a deciduous forest. Trees in this area included large individuals of *Juglans nigra* L. as well as *Celtis occidentalis* L., *Prunus serotina* Ehrh., *Ulmus rubra* Muhl., *Carya ovata* (Mill.) K. Koch, and *Quercus* spp. The ground cover included *Toxicodendron radicans* (L.) Kuntze, *Ribes* sp., *Rubus*

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FIGURE 1. *Trillium erectum* at the Green Oaks Biological Field Station, Knox County, Illinois, April 27, 2018. Photo by D. James Mountjoy.

sp., *Parthenocissus quinquefolia* (L.) Planch., *Arisaema triphyllum* (L.) Schott, *Erythronium albidum* Nutt., and *Dicentra cucullaria* (L.) Bernh.

Case (2002) has suggested that records of *Trillium erectum* from west of the primary range may represent hybrids with *Trillium flexipes* Raf., but the plants reported here appeared to be typical examples of *Trillium erectum* var. *erectum*, with dark maroon ovaries. Wisconsin is not listed as falling within the distribution of *Trillium erectum* in Case and Case (1997) or the USDA PLANTS database (USDA NRCS 2018), but 10 Wisconsin specimen records from four counties are listed in the Flora of Wisconsin database (Consortium of Wisconsin Herbaria, 2020). It is possible that at least some of these records may represent hybrids or escapes from gardens, but it seems that it would be worthwhile for these specimens to be examined, as the true distribution of *Trillium erectum* in the Midwest may be underestimated.

As *Trillium erectum* is an attractive plant that is occasionally grown in gardens, it is worth considering whether this population may have been planted at the site. Knox College has owned the Green Oaks Biological Field Station (704 acres) since 1958, and there does not appear to be any recollection of this species being planted at Green Oaks during this time (Peter Schramm, pers. comm.). The area where the population was discovered is less than 100m from an area that was used as a residence and farm yard by previous owners, so it is possible that plants were introduced during that time period, however, the lack of wild popu-

lations in Knox County or adjacent areas from which plants could be transplanted may make that less likely. On the other hand, the fact that Green Oaks has had an extensive area of forest cover for centuries as indicated by the presence of many ancient individuals of *Quercus alba* L. (Shepard n.d.) and relictual species such as *Hemidactylium scutatum* (Four-toed Salamander, Meyer et al. 2002), as well as a diverse flora with many woodland species that have high Coefficient of Conservatism values (Taft et al. 1997) indicates that this property serves as a valuable and long-standing reserve for biodiversity.

Specimen citation. Illinois, Knox County. Knox College's Green Oaks Biological Field Station, ca. 4 miles south of Victoria; woods to the south of 'South Prairie' and west of Schurr Hall; 40°58′13″, 90°05′42″; over 100 stems noted in area mostly close to stream. Photographic voucher, April 27, 2018 (Figure 1) (ILLS 278430).

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NOTEWORTHY COLLECTION

FIRST RECORD OF THE INVASIVE JAPANESE STILTGRASS, *MICROSTEGIUM VIMINEUM* (POACEAE), IN CANADA.

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Significance of the Report. The invasive grass *Microstegium vimineum* (Trin.) A. Camus is reported for the first time from Canada.

Previous Knowledge. *Microstegium vimineum* (Trin.) A. Camus (Japanese Stiltgrass) is an annual grass native to China, India, Japan, Korea, Taiwan, Malaysia, and portions of the Caucasus (Ohwi 1965). It has been introduced into other parts of Asia and into Europe, Africa, and Central America (Weber 2003, EPPO 2020). Japanese Stiltgrass is also known as Nepalese Browntop, Nepal Microstegium, and Packing Grass. *Microstegium vimineum* was first recorded in North America in 1919, growing along a creek bank in Knoxville, Tennessee (Fairbrothers and Gray 1972). It has since been introduced and become established in the northeastern, southeastern, and midwestern states, as well as in Texas (USDA NRCS 2020). The closest known record of *M. vimineum* to Canada is located in Niagara County, New York (iMapInvasives Presence record #1039405) (NatureServe 2020), which is approximately 20 km from the new Canadian population reported here, in Short Hills Provincial Park, Niagara Regional Municipality, Ontario.

Considered an invasive species in North America and a potential threat to economic and ecological resources, *Microstegium vimineum* is regulated as a pest in Canada under the Plant Protection Act (Canadian Food Inspection Agency 2019). It is capable of invading streambanks, floodplains, mesic woodlands, forests, swamps, and other wetlands as well as disturbed habitats like roadsides, trail edges, early successional fields, wet fields, lawns, thickets, and

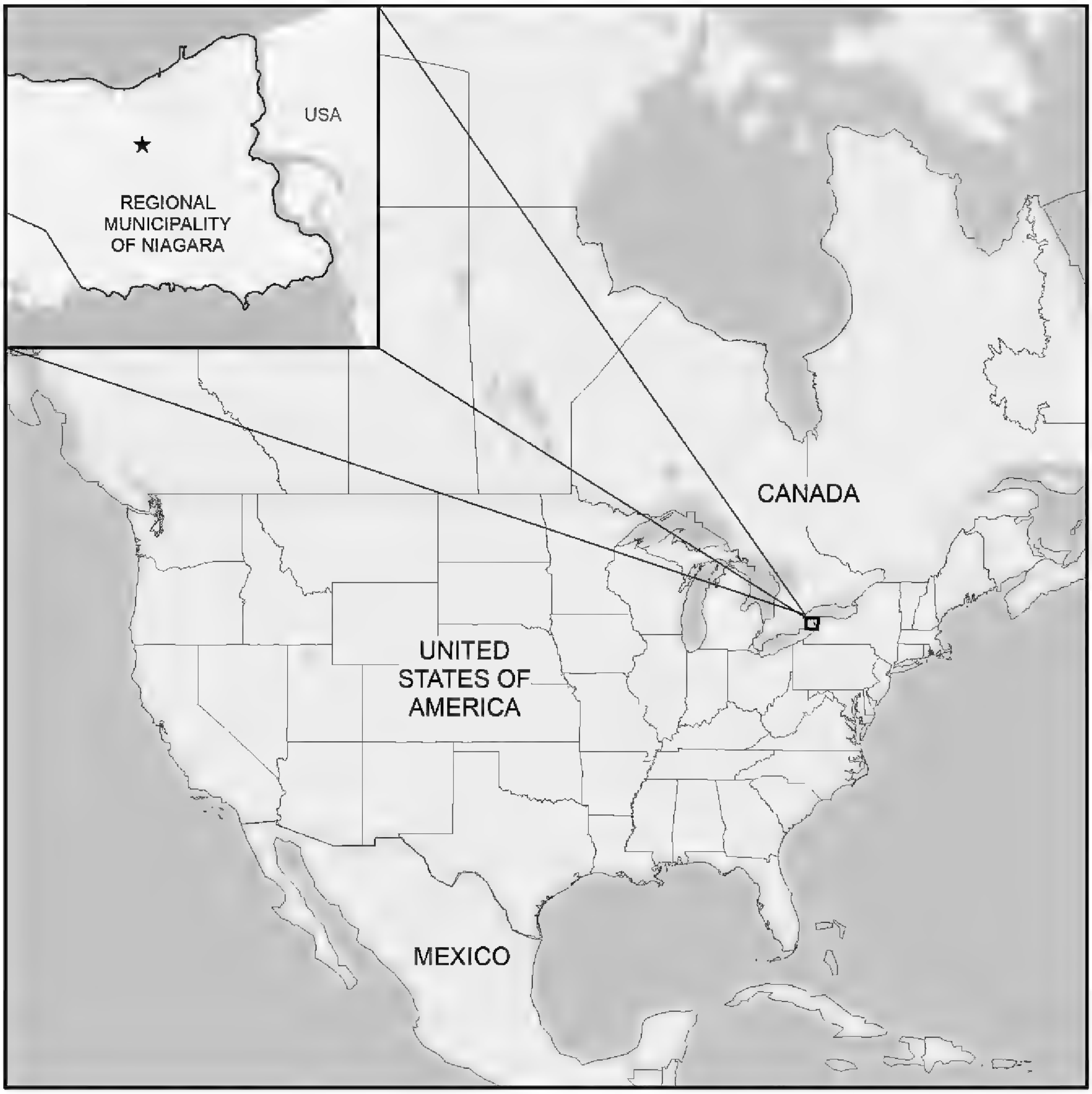

FIGURE 1: Map showing the location of the first collection of *Microstegium vimineum* in Canada, indicated by a black star in the inset. The North American map provides context.

gardens (Fairbrothers and Gray 1972; Hunt and Zaremba 1992; Redman 1995; Cole and Weltzin 2004; Huebner 2010). In addition to rapidly colonizing naturally or anthropogenically disturbed areas, *M. vimineum* can also become established in shaded environments (Barden 1987). It can form dense monocultures (Hunt and Zaremba 1992) and seed banks have been reported to remain viable for at least three years (Barden 1987). Additionally, field experiments have demonstrated that *M. vimineum* can suppress native tree regeneration (Flory and Clay 2010a) and reduce native plant biomass and species richness through direct competition (Flory and Clay 2010b).

Discussion. *Microstegium vimineum* was observed on September 8, 2019 while botanizing in Short Hills Provincial Park, Niagara Regional Municipality, Ontario (Figure 1). Short Hills Provincial Park is a mosaic of natural and cultural vegetation communities including deciduous forest, woodland, regenerating old

field meadows and coniferous plantations. These communities are interspersed by extensive trail systems utilized by pedestrians, cyclists and equestrians. Short Hills Provincial Park covers 688 ha of land which the Ontario government initially began acquiring in the 1960s, and to date, approximately 15% of the park remains active agricultural land (Ministry of Natural Resources and Forestry 2019).

The first *Microstegium vimineum* specimen was collected in the western portion of Short Hills Provincial Park, adjacent to the Bruce Trail. It was located at the interface of an open old field meadow composed of cool season grasses and a woodland dominated by *Juglans nigra* L. (Black Walnut). Soils in the area appeared to be primarily comprised of sandy loam. The individuals initially encountered occurred in two dense patches. The first of these was approximately one meter by four meters in area, approximately ten meters east of the trail. The second patch was approximately 20 meters northeast of the first patch, approximately ten meters by ten meters in area, situated approximately two meters from the trail. No individuals in either patch were observed flowering or fruiting. Associated species growing in the general area included regenerating trees and shrubs (*Fraxinus pennsylvanica* Marshall, *Juglans nigra*, and *Rubus allegheniensis* Porter), abundant exotic cool season grasses (*Phleum pratense* L., *Poa pratensis* L. subsp. *pratensis* and *Dactylis glomerata* L.), and forbs typical of disturbed habitats (*Monarda fistulosa* L., *Agrimonia gryposepala* Wallr., *Plantago rugelii* Decne., *Medicago lupulina* L., and *Solidago canadensis* L. var. *canadensis*).

Additional searching along the Bruce Trail further northeast of the initial collection location revealed larger, contiguous patches of *Microstegium vimineum* that dominated the ground layer in areas adjacent to the trail, extending into deciduous woodland, deciduous forest, and meadow vegetation communities. The second collection was made in a *Juglans nigra* dominated woodland, growing in semi-shaded conditions where *M. vimineum* was the dominant vegetation in the ground layer (Figure 2). Several individuals at this location had developed inflorescences. After preliminary field surveys, R. Gould (pers. comm. November 20, 2019) confirmed that the extent of the infestation spanned several hectares of woodland, forest, and meadow in the northwest portion of Short Hills Provincial Park. It should be noted that M. J. Oldham and others did not note the presence of *M. vimineum* during extensive botanical surveys in Niagara Regional Municipality in 2006, 2007, and 2008 (Oldham 2010). Additionally, in 2014 J. Consiglio visited the same section of Short Hills Provincial Park where *M. vimineum* is now dominant and did not observe this species.

The precise origin of the first invasion of *Microstegium vimineum* in Canada is currently unknown. Mehrhoff (2000) suggested seeds may be naturally dispersed by water, as the small caryopses are capable of floating, or may become attached to travelling animals. Anthropogenic dispersal via vehicles and clothing has also been noted (Mehrhoff 2000) and is likely the reason for the rapid spread of *M. vimineum* in other areas (Rauschert et al. 2009). Short Hills Provincial Park is surrounded by a network of roads, so seeds or a vegetative propagule could easily have been introduced on vehicles travelling from the United States.

FIGURE 2: A dense patch of *Microstegium vimineum* growing in the understory of a woodland dominated by *Juglans nigra*. Photo by Corey W. Burt.

Additionally, the Bruce Trail is a well-known hiking trail which is used by Ontario residents as well as American visitors.

As the landscape matrix surrounding Short Hills Provincial Park is primarily composed of agricultural lands, it is possible that viable seeds of *M. vimineum* travelled to Canada as a contaminant in hay, forage, or other agricultural seed mixes. It is also worth noting that dumped potting soil and horticultural plant material which likely originated from adjacent private properties was observed in the northwestern portion of Short Hills Provincial Park near the largest observed patch of *M. vimineum*. Therefore, it is also possible that *M. vimineum* could have been introduced to Short Hills Provincial Park as a soil contaminant.

Barden (1987) noted that *Microstegium vimineum* was slow to establish in areas of undisturbed vegetation but established rapidly in anthropogenically disturbed areas which had been mowed. The trail system in Short Hills Provincial Park is mowed, and dense patches of *M. vimineum* were frequently observed along mowed trail edges. It is likely that *M. vimineum* seeds and/or fragmented vegetative propagules were dispersed throughout Short Hills Provincial Park via trail mowing, based on patch proximity to the trail system and the plant's ability to root readily from the nodes.

The Canadian Food Inspection Agency (CFIA) and Ontario Parks have been notified of this sizable *Microstegium vimineum* population. Ontario Parks staff are working to map and measure the exact extent of the population within Short

FIGURE 3: Vegetative culms of *Microstegium vimineum*, clearly displaying the distinct line of silver hairs along the midvein of the blade. Photo by Corey W. Burt.

Hills Provincial Park, and CFIA staff will be conducting targeted surveys outside of the park in adjacent lands. A Notice of Prohibition of Movement was issued in Short Hills Provincial Park which restricts the movement of soil and plant material, and control measures are anticipated to take place in spring 2020 (S. Leone pers. comm. November 2019; R. Gould pers. comm. November 2019). Local botanists should keep watch for this species in other counties and regions within Ontario and in other provinces to prevent further establishment of this invasive grass in Canada.

Diagnostic Characters. *Microstegium vimineum* is a sprawling annual grass capable of growing up to 1 m in height (Gleason and Cronquist 1991; Thieret 2003; Chen and Phillips 2006). It readily roots from the nodes and forms extensive dense mats. Ehrenfeld (1999) reported several populations of a rhizomatous, perennial form of *M. vimineum*; however, this is an error derived from a misidentification. Mehrhoff (2000) stated that no herbarium specimen of this alleged perennial form had been deposited to an herbarium, and the morphological characters presented were similar to the native grass *Leersia virginica* Willd. One of the most notable characters of *M. vimineum* is the distinct line of silver

FIGURE 4: Herbarium specimen (NHIC accession #09651) of *Microstegium vimineum.*

hairs along the midvein of the lanceolate leaves. Redman (1995) reported that this was absent in early season, in specimens in fruit and in flower, and in specimens growing in full sun. Contrary to Redman's findings, the *M. vimineum* observed in Short Hills Provincial Park had silver hairs along the midvein in specimens that were flowering and in specimens that had been growing in full sun (Figures 3 and 4). The inflorescences are arranged on terminal and axillary racemes and may be cleistogamous or chasmogamous (Gibson et al. 2002; Theiret 2003). Pedicels are ciliate (Gleason and Cronquist 1991) and spikelets occur in pairs, one pedicellate, the other sessile (Chen and Phillips 2006). Fertile

lemmas may be awned or awnless (Gleason and Cronquist 1991). Several previous authors have designated varietal status based upon the presence or absence of awns (Fernald 1950; Hitchcock 1951; Bor 1960); however, a morphological analysis of New Jersey specimens concluded that this condition is variable and that these subspecific ranks should not be recognized (Fairbrothers and Gray 1972). Specimens collected from Short Hills Provincial Park sported long, twisted awns.

Microstegium vimineum is morphologically similar to *Leersia virginica* and *Brachyelytrum* P. Beauv. species. It can be readily distinguished vegetatively from both taxa by the prominent line of silver hairs along the midvein of the leaf blades. There is also a distinct phenological difference, as *L. virginica* and *Brachyelytrum* species both fruit in August, while *M. vimineum* does not begin fruiting until late September to early October (Mehrhoff 2000; Stephenson 1971). *Leersia virginica* has distinctly pubescent nodes and rhizomes with overlapping scales whereas *M. vimineum* has glabrous nodes and lacks rhizomes (MICHIGAN FLORA ONLINE 2011). *Brachyelytrum* species have larger spikelets which are equal to or greater than 8 mm in length (Theiret 2003; MICHIGAN FLORA ONLINE 2011), while *M. vimineum* spikelets are 3.7–6.6 mm long, excluding awns (Theiret 2003).

Specimen Citations. ONTARIO: Regional Municipality of Niagara: Bruce Trail, Short Hills Provincial Park, Pelham. Black Walnut dominant cultural woodland. Dominant species in ground layer. Thousands of plants throughout cultural woodland. Some fruiting, mostly vegetative. First Canadian Record. 43.10204668, –79.28996053. September 8, 2019. *C. Burt, J. Consiglio CBJC-2019-070* (NHIC).

ONTARIO: Regional Municipality of Niagara: Bruce Trail, Short Hills Provincial Park, Pelham. Cultural Savannah; ELC code CUS1; Black Walnut dominant. One vegetative colony adjacent trail (1 × 4 m) at 17T 638103 4772718 and one large clump (10 m × 10 m) approx. 10 m south of trail at 17T 638107 4772709. A second collection was made trailside in ELC code CUW1 at 17T 639152 4773567 with some fruiting but mostly vegetative. Associated species: *Fraxinus pennsylvanica*, *Juglans nigra*, *Phleum pratense*, *Monarda fistulosa*, *Agrimonia gryposepala*, *Rubus allegheniensis*, *Poa pratensis*, *Dactylis glomerata*, *Plantago rugelii*, *Medicago lupulina*, *Solidago canadensis*. September 8, 2019. *C. Burt*, *J. Consiglio CBJC-2019-067* (HAM).

ACKNOWLEDGMENTS

Thank you to Nadia Cavallin and Joseph Mentlik who provided assistance using microscope photography software and provided a digital scanned copy of the HAM herbarium specimen, to Ewa Kielasinska who created the location map, to Ron Gould and CFIA staff for providing additional comments and input on the population of *Microstegium vimineum* in Short Hills Provincial Park, and to Dawn Renfrew for providing feedback on an earlier draft of this paper.

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NOTEWORTHY COLLECTION

LANDOLTIA PUNCTATA (ARACEAE), A NEW DISTRIBUTIONAL RECORD FOR THE OZARKS

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Significance of the Report. First report of *Landoltia punctata* G. Mey.) D.H. Les & D.J. Crawford within the Ozark physiographic region.

Previous Knowledge. *Landoltia punctata* (G. Meyer) D. H. Les and D. J. Crawford (=*Spirodela punctata* (G. Meyer) C. H. Thomspson or *Spirodela oligorrhiza* (Kurz) Hegelmaier) (dotted duckmeat) is native to Australia and Southeast Asia (Landolt 1986). The first record of this species in North America is a 1930 collection from Kansas City, Missouri (Saeger 1934). Jacono and Pfingsten (2020) reviewed thousands of records of this species from North America and did not find any records predating the 1930 collection, indicating that it was introduced to North America. *Landoltia punctata* has been reported from 22 other states in the United States with records from Alabama, Arkansas, Arizona, California, Florida, Georgia, Hawaii, Illinois, Kentucky, Louisiana, Maryland, Massachusetts, Mississippi, Missouri, North Carolina, Oklahoma, Oregon, Pennsylvania, South Carolina, Tennessee, Texas, and Virginia (USDA, NRCS 2020).This species has been previously shown to occur in central and southeast Arkansas and three counties in Missouri (USDA, NRCS 2020; Figure 1). In Arkansas, it has been recorded from Pulaski, Jefferson, Arkansas, Monroe, Lincoln, Desha, Ashley, and Clark counties located on the Mississippi River Alluvial Plain and West Gulf Coastal Plain (Smith 2017). In Missouri, it was also recorded from the Mississippi River Alluvial Plain (Charles and Stoddard counties) as well as the Dissected Till Plain (Jackson County) (Yatskievych 1999).

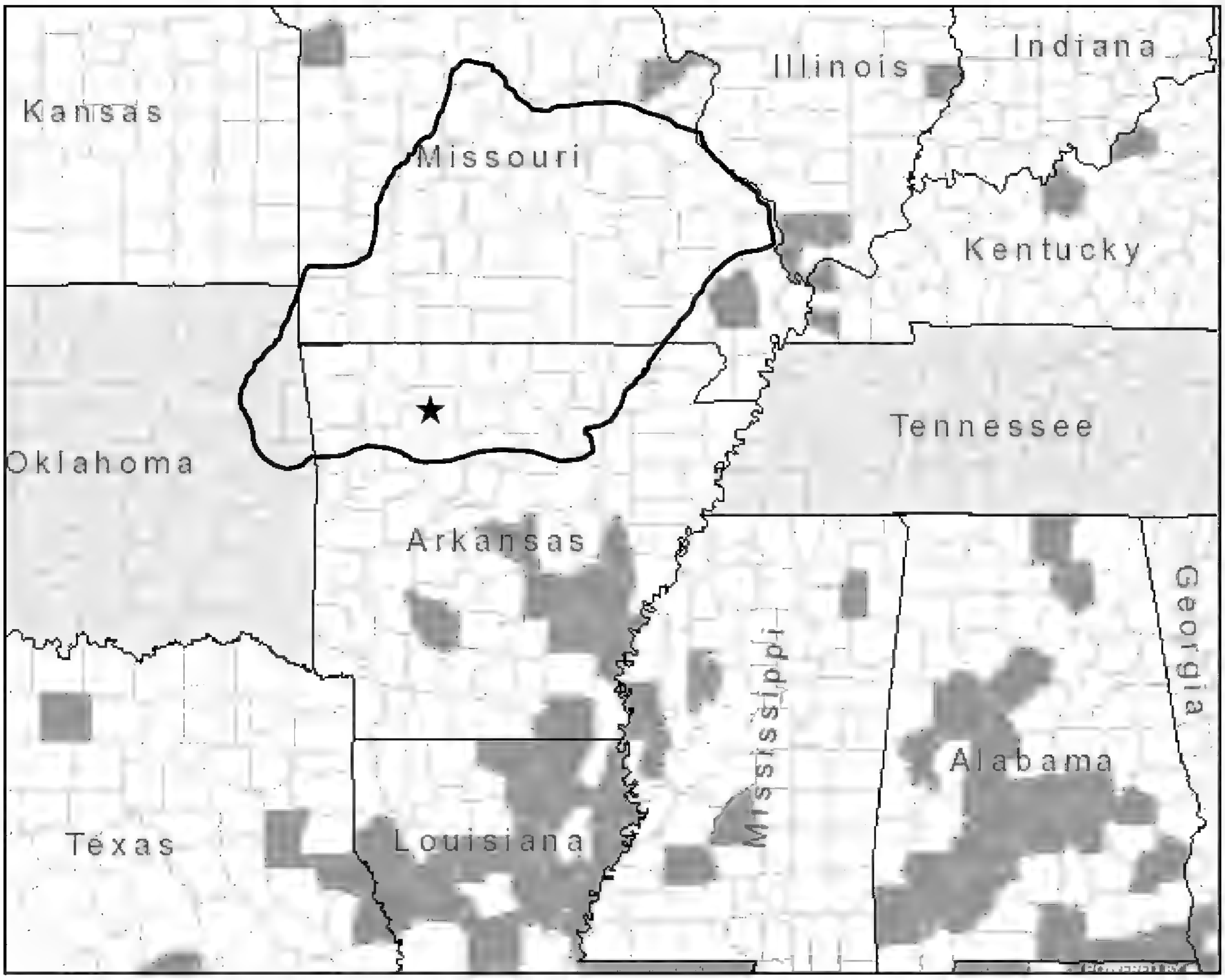

FIGURE 1. The county distribution of *Landoltia punctata* in Arkansas and nearby states (shaded counties) and the new record in Newton County, Arkansas (star). The line represents the approximate boundary of the Ozark physiographic region. The species is present in Oklahoma and Tennessee, but no county records are available. The base map is from the USDA, NRCS (2020).

However, there are no previous records of *L. punctata* from the Ozark physiographic region (Rafferty 2001). Unlike other physiographic regions in Arkansas and Missouri, the Ozarks have a predominantly karst geology with hilly to mountainous topography, where lentic aquatic systems favored as habitat by *L. punctata* are uncommon.

Discussion. This new population of *L. punctata* was found in Fowler's Lake, a small reservoir located at Buffalo National River, Newton County, Arkansas, on October 11, 2019. Fowler's Lake is located at the top of Cave Mountain (elevation 702 m) where it is isolated from other water bodies. The lake is surrounded by oak–hickory woodlands and is in the vicinity of a privately-owned pasture with grazing cattle. *Landoltia punctata* was found floating in the water close to shore among *Lemna minor* L., *Spirodela polyrrhiza* (L.) Schleid., and other aquatic plants. It is possible that *L. punctata* has a wider range in the Ozarks than is currently known due to its striking resemblance to two common duckweed species in the Ozarks, *L. minor* and *S. polyrrhiza*, with which it can be confused. A survey of the duckweed species in the Ozark region is needed to determine the distributional extent of this non-native species because it has the potential to invade other aquatic systems in the region and cause disruption of eco-

logical functioning, particularly the risk of competition with and exclusion of native duckweed species. Previous work reported that invasive duckweed species tend to outcompete native duckweeds in both field and laboratory experiments (Paolacci et al. 2016; Gérard et al. 2018). Competition with invasive duckweeds is more likely between related species because of their similar growth form and their occurrence on the surface of quiet waters (Gopaul and Goel 1993).

Diagnostic Characters. *Landoltia punctata* can be confused with other duckweed species. It has bright green fronds and resembles *Lemna minor* when observed from the top and *Spirodela polyrrhiza* when observed from the bottom (Figure 2). However, the fronds of *L. punctata* are smaller (1–3 mm wide) than both of these other species (Yatskievych 1999; Jacono and Pfingsten 2020). Its mature fronds are also more oval shaped (1.5–2 times longer than wide) and have fewer roots per frond (2–7) than *S. polyrrhiza* (5–12) (Les and Crawford 1999; Borman et al. 1997). Like other duckweed species, *L. punctata* reproduces mainly by asexual reproduction, producing daughter fronds attached to the parent frond in colonies of two to five (Cronk and Fennessy 2001). Les and Crawford (1999) established the genus *Landoltia* after finding molecular evidence that *L. punctata* was generically distinct from *Lemna* and *Spirodela*. The species is sometimes treated as *Spirodela punctata* (G. Mey.) C. Thomps. Ward (2011) rejected circumscription of the genus *Landoltia*. He selected a specimen of *S. intermedia* W. Koch, a native South American species, as the neotype for *Lemna punctata* G. Mey (see Wiersema 2014). Based on this neotype, Ward (2011) argued that *S. punctata* is native to the New World and that the correct name for the Asian/Australian species should be *S. oligorrhiza* (Kurz) Hegelm. Wiersma (2014) rejected Ward's proposal on the basis that it is too speculative and disruptive to the nomenclature of these species.

Specimen Citation. ARKANSAS. NEWTON CO., Buffalo National River, Fowler's Lake. 35°57′13.68″, –93°24′56.15″, L. Kissoon-Charles, C.R. Cheri, and D.E. Bowles, October 11, 2019 (in 4% buffered formalin) [HTLN-223]. Reference specimens are in the collection of the National Park Service, Heartland Inventory and Monitoring Network (HTLN), Wilson's Creek National Battlefield, Republic, Missouri. Sparsely distributed along quiet margins of the reservoir, especially along the southern and western margins. Associated species: *Lemna minor, Spirodela polyrrhiza, Cyperus erythrorrhizos* Muhl., *Dulichium arundinaceum* (L.) Britton, *Eleocharis quadrangulata* (Michx.) Roem. & Schult., *Scirpus cyperinus* (L.) Kunth, *Leersia oryzoides* (L.) Sw., *Potamogeton pusillus* L., *Sparganium androcladum* (Engelm.) Morong, *Typha latifolia* L., *Bidens cernua* L., *Bidens frondosa* L., *Eclipta prostrata* (L.) L., *Brasenia schreberi* J.F.Geml., *Lycopus virginicus* L., *Utricularia gibba* L., *Ludwigia palustris* (L.) Elliott, *Persicaria setacea* (Baldwin) Small, *Boehemeria cylindrica* (L.) Sw. Reference specimens for these species are in the collection of the HTLN.

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We thank Michelle Bowe, Missouri State University, for reviewing an earlier version of this manuscript. James Skean kindly provided constructive comments that improved the manuscript.

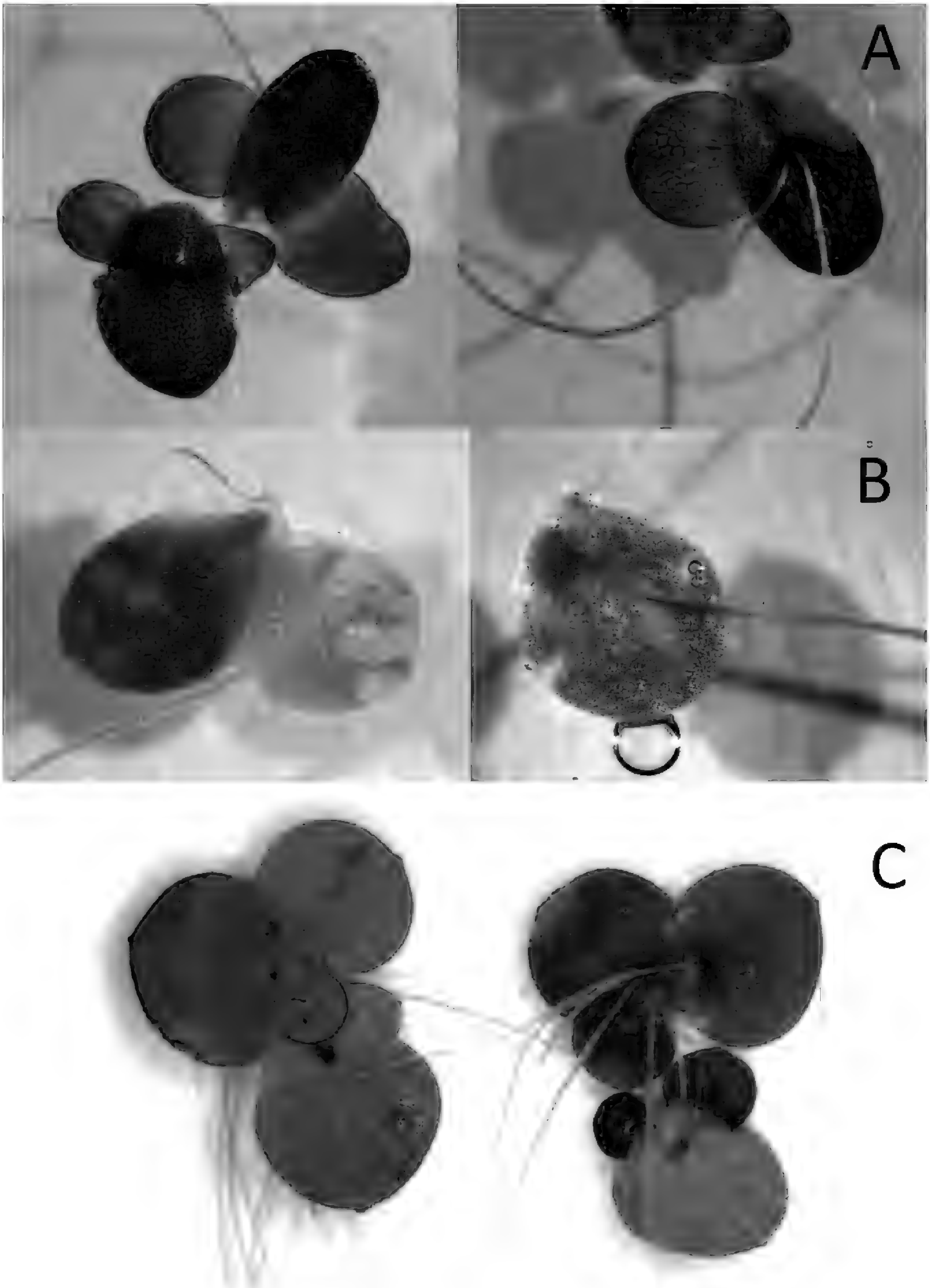

FIGURE 2. Duckweeds from Fowler Lake. (A) *Landoltia punctata*, (B) *Lemna minor*, and (C) *Spirodela polyrrhiza*. Photos of each species are, respectively, of the upper (left-side photos) and ventral (right-side photos) aspects. Photos by David E. Bowles.

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NOTEWORTHY COLLECTION

THE DISCOVERY OF *ERIOPHORUM RUSSEOLUM* FR. SUBSP. *LEIOCARPUM* NOVOSELOVA (CYPERACEAE), WHITE-BRISTLED RUSSET COTTONGRASS, IN MICHIGAN.

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Significance of the Report. The first records of *Eriophorum russeolum* Fries for Michigan. These plants belong to *E. russeolum* subsp. *leiocarpum* Novoselova, one of two subspecies known from North America.

Previous Knowledge. *Eriophorum russeolum* Fries subsp. *leiocarpum* Novoselova lies within the *Eriophorum russeolum–E. scheuchzeri* complex containing *E. chamissonis* C.A. Meyer, *E. russeolum*, and *E. scheuchzeri* Hoppe (Cayouette 2004). Of these, only *E. russeolum* subsp. *leiocarpum* and *E. scheuchzeri* have spikelets with white bristles, however, the latter is restricted to Alaska and British Columbia (Cayouette 2004). In North America, the range of *E. russeolum* subsp. *leiocarpum* is from northwestern North America (Alaska, Yukon Territory) to central Canada and north (Prairie provinces, Northwest Territories, Nunavut), with scattered sites in eastern North America (Ontario, Quebec, Labrador, New Brunswick, and Nova Scotia) including occurrences in Minnesota and Wisconsin, the southern extent of its range in North America (Cayouette 2004). *Eriophorum russeolum* subsp. *russeolum* (russet cottongrass), having spikelets with orange-brown bristles, is restricted to eastern North America in the Maritime provinces, Quebec, and with collection records in Ontario centered around James Bay (Cayouette 2004, Meades et al. 2004).

In Wisconsin, *Eriophorum russeolum* subsp. *leiocarpum* is documented in the four northernmost counties and is a species of Special Concern (WI DNR 2020). It is not considered a rare species in Minnesota and Ontario, where it is ranked SNR and S5, respectively, by NatureServe (2020). Numerous collection records place it throughout the forested ecoregions of Minnesota (MNBA 2020). Its range in Ontario extends from the north shore of Lake Superior to the James Bay

Lowlands (Consortium of Midwest Herbaria 2020, Meades et al. 2004), although this is based on a very limited number of collection records. Habitat for the species in Wisconsin includes poor and boreal rich fens (WI DNR 2020) while poor and rich fens and other peatland-associated wetlands are described as habitats in Minnesota (Smith 2018).

Eriophorum russeolum subsp. *leiocarpum* has sometimes been included in synonymy under *E. chamissonis* (e.g., Ball and Wujek 2002, albeit as *E. russeolum* var. *albidum* F. Nylander). Cayouette (2004), however, concludes that *E. chamissonis* is restricted to Alaska and British Columbia and that the Nylander's epithet *albidum*, whether at the varietal or subspecific level, does not pertain to either *E. russeolum* or *E. chamissonis*.

Discussion. In June 2019, we discovered *Eriophorum russeolum* in two locations in Michigan's Upper Peninsula, one in Marquette County, south of Gwinn, and the other in Keweenaw County, west of Gay. The two localities are approximately 130 km apart. Both collection sites have similar vegetation and would be considered poor fens (Cohen et al. 2015; Cohen et al. 2020). At the Keweenaw County site, 130 fruiting culms of *E. russeolum* subsp. *leiocarpum* were seen in a 0.1 ha area within an approximate 1.4 ha fen, part of a larger (over 40 ha) wetland complex with a perimeter conifer swamp and boreal forest. *Carex exilis* Dewey was the dominant associate with woody plant associates including *Alnus incana* (L.) Moench subsp. *rugosa* (Du Roi) R.T. Clausen, *Aronia prunifolia* (Marshall) Rehder, *Betula pumila* L., *Chamaedaphne calyculata* (L.) Moench, *Kalmia polifolia* Wangenh., *Larix laricina* (Du Roi) K. Koch (stunted), and *Myrica gale* L. Other herbaceous associates included *Arethusa bulbosa* L., *Carex lasiocarpa* Ehrh., *Iris versicolor* L., *Menyanthes trifoliata* L., *Oclemena nemoralis* (Aiton) Greene, and *Sarracenia purpurea* L. Of note, a colony of a similar *Eriophorum*, *E. vaginatum* L., occurred to the south.

At the Marquette County location, multiple colonies of *E. russeolum* subsp. *leiocarpum* were observed within an approximate 10 ha area lying within the westernmost portion of a large fen-conifer swamp complex. One area had small colonies of 10 to 20 fruiting culms for a total of 90 in the immediate area. Two nearby sites had 400 and 40 fruiting culms, respectively. Another had 200+ fruiting culms. Common woody plant associates included *Larix laricina*, *Betula pumila*, *Andromeda polifolia* L. var. *latifolia* Aiton, and *Chamaedaphne calyculata* and the most frequent herbaceous plant associates were *Equisetum fluviatile* L. and *Carex lasiocarpa*. Less common woody plant associates included *Acer rubrum* L., *Alnus incana* subsp. *rugosa*, *Aronia prunifolia*, *Dasiphora fruticosa* (L.) Rydb., *Kalmia polifolia*, and *Thuja occidentalis* L. Other herbaceous associates included *Arethusa bulbosa*, *Carex chordorrhiza* L. f., *Carex exilis*, *Carex interior* L., *Carex livida* (Wahlenb.) Willd., *Eriophorum angustifolium* Honck., *Eriophorum viridicarinatum* (Engelm.) Fernald, *Glyceria canadensis* (Michx.) Trin., and *Solidago uliginosa* Nutt.

Diagnostic Characters. *Eriophorum russeolum* subsp. *leiocarpum* and *E. vaginatum* are the only taxa in the genus known from the Great Lakes Region that have solitary terminal white spikelets. The rhizomatous growth form of *E. russeolum* subsp. *leiocarpum* with solitary culms (Figures 1 and 2) contrasts, however, with the strongly cespitose growth form of *E. vaginatum* (MICHIGAN

FIGURE 1. Colony of the rhizomatous *Eriophorum russeolum* subsp. *leiocarpum* (inset: mature spikelet). Photos by Rob Routledge.

FIGURE 2. Fruiting culm, rhizome (arrow), and vegetative shoots of *Eriophorum russeolum* subsp. *leiocarpum.* Photo by Janet Marr.

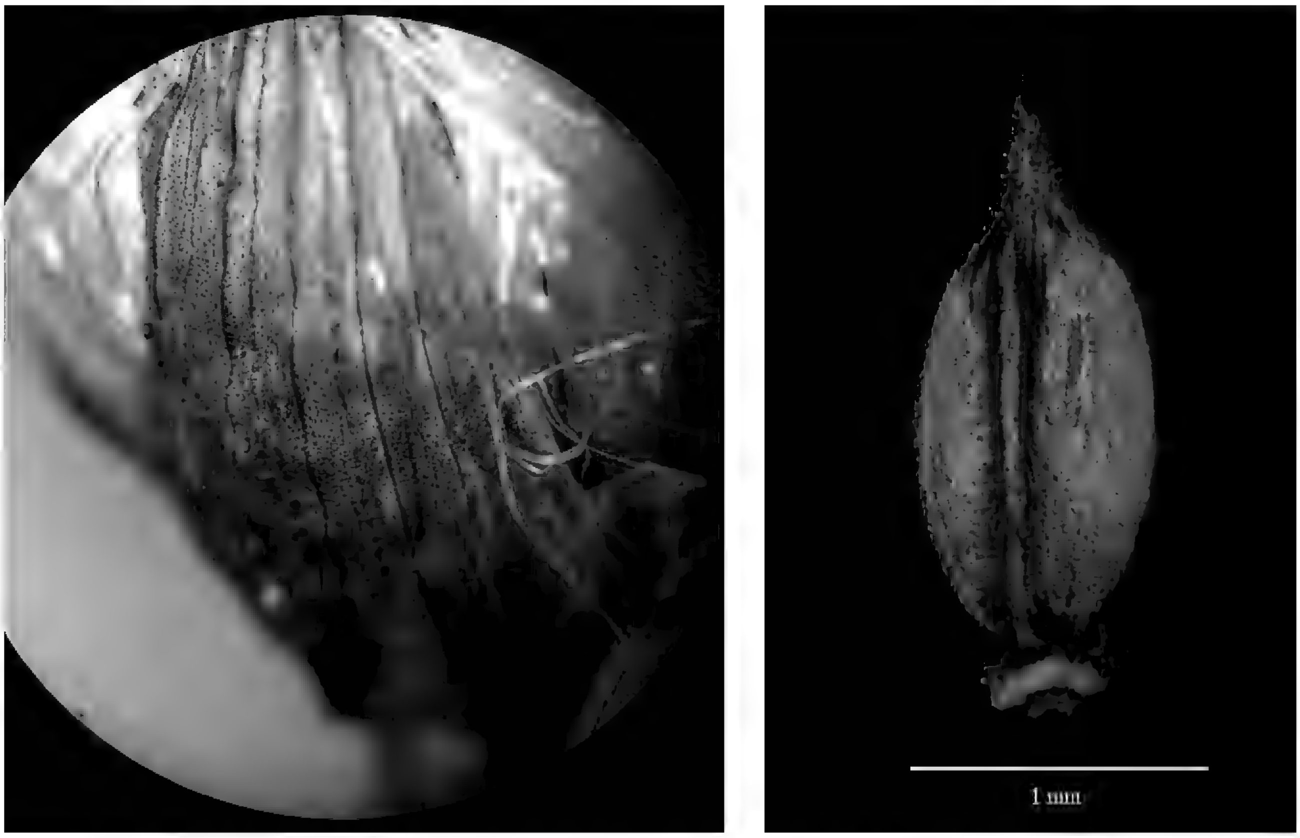

FIGURE 3. Lowest sterile scale showing several prominent ribs (left) and mature achene (right) of *Eriophorum russeolum* subsp. *leiocarpum.* Photos by A. Graeff (left) and B. S. Walters (right).

FLORA ONLINE 2011). The mature achenes of the two species are quite distinct from each other and allow identification when mature spikelets are available (MICHIGAN FLORA ONLINE 2011). The achene of *E. russeolum* subsp. *leiocarpum* has a long tapering beak, whereas a beak is absent from the achenes of *E. vaginatum* (Figure 3). Furthermore, the lowest sterile scale in *E. russeolum* subsp. *leiocarpum* is large (1–2 cm in length) with 3–10 prominent ribs (Figure 3), while in *E. vaginatum*, this scale is up to 1 cm in length and with only 1 (–3) slender ribs (Smith 2018).

Specimen Citations. MICHIGAN: Keweenaw County, west of Gay; T56N R31W, NE¼ / SW¼ / SE¼ Sec 24; UTM (NAD83): 410749E 5231641N 16T; June 27, 2019, *Janet Marr 4284* (MICH). Marquette County, south of Gwinn; T44N R25W SE¼ / NE¼ Sec 16; UTM (NAD83): 466835E 5117759N 16T; June 21, 2019, *Alex Graeff 0027* (MICH). South of Gwinn; T44N R25W SW¼ Sec 10; UTM (NAD83): 466934E 5118270N 16T; June 21, 2019, *Rob Routledge 0001* (MICH)

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NOTEWORTHY COLLECTION

THE DISCOVERY OF *UTRICULARIA OCHROLEUCA* (LENTIBULARIACEAE), YELLOWISH-WHITE BLADDERWORT, IN MICHIGAN

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Significance of the Report. The first record of *Utricularia ochroleuca* R. W. Hartman (Yellowish-white Bladderwort or Northern Bladderwort) in Michigan.

Previous Knowledge. Originally described from northern Europe in 1857, *Utricularia ochroleuca* was rarely recognized as distinct from *U. intermedia* Hayne for many years. *Utricularia ochroleuca* has been regarded as a vegetative apomict thought to be of hybrid origin with *U. intermedia* and *U. minor* L. parentage, as it exhibits floral and vegetative features intermediate between the two taxa and is able to persist and disperse via winter buds (turions) (Taylor 1989; Crow 2015a,b). *Utricularia ochroleuca* has a circumboreal distribution, occurring in northern regions across Eurasia, where it is considered very rare (Adamec 2020), and in North America from relatively few localities, confirmed by documenting herbarium specimens examined by Crow, from Nova Scotia and Quebec west to Ontario, Nunavut, Northwest Territories, Manitoba, Alberta, British Columbia, Yukon Territory and Alaska, south to northern Michigan (collections cited herein), Wyoming, Montana, Washington, Oregon, northern California, and Colorado (Ceska and Bell 1973; Rice 2005; 2012; Crow 2015b; Brouillet et al. 2020). It appears to be better established in northwestern North America, although this is surely an under-collected species. For instance, in the context of a study of the aquatic plants of Yellowstone National Park, Hellquist et al. (2014) reported *U. ochroleuca* as new to Wyoming; in support of their study, Crow (unpublished data) found 18 collections of this species in the Yel-

FIGURE 1. Comparison of spurs on lower lip: *Utricularia intermedia* (left); *U. ochroleuca* (right). Photos by Rob Routledge.

lowstone National Park Herbarium (YELLO), several of which were actually collected before their study, but that had been misidentified. Likewise, *U. ochroleuca* was unknown in Montana until 2012, when Crow identified a specimen sent for confirmation by Peter Lesica (Manual of the Flora of Montana project, University of Montana Herbarium, MONTU). The locality nearest to the site of our discovery of this species in the Upper Peninsula of Michigan is an isolated population in the Thunder Bay District of Ontario, ca. 200 km directly northwest of the Michigan site on the Keweenaw Peninsula. (*Catling, Brownell & McKay* s.n. August 14, 1984, DAO, MICH).

Discussion. *Utricularia ochroleuca* was discovered in flowering condition on August 11, 2019, at a site on the Keweenaw Peninsula by R. Routledge, identifiable based on the short flower spur, which contrasts with the spur of *U. intermedia* which is nearly the full length of, and appressed to, the lower lip (Figure 1). The site was revisited August 30, 2019, where A. Graeff collected herbarium voucher specimens of *U. ochroleuca* (Figure 3). Two specimens were collected from different sites in close proximity at the edge of an old beaver flooding on the West Branch Eagle River at the Cliff Mine site.

One specimen (*Graeff 0036*) was collected on the north edge of the flooding. The plants were submersed in shallow water among woody debris at the edge of the pond (Figure 2), where some individuals were entangled among plants such as *Eleocharis acicularis* (L.) Roem. & Schult., *Equisetum arvense* L., *Juncus articulatus* L., *Bidens cernua* L., *Equisetum fluviatile* L., *Leersia oryzoides* (L.) Sw., *Impatiens capensis* Meerb., *Cerastium* sp., *Persicaria* sp., *Typha latifolia* L., *Cicuta bulbifera* L., and *Agrostis* sp.

The other specimen (*Graeff 0037*) was collected on the south edge of the

FIGURE 2. *Utricularia ochroleuca* in habitat. Photo by Alex Graeff.

flooding where it was growing with *U. intermedia* and *U. minor* among culms of *Eleocharis* sp. Individuals of *U. ochroleuca* were rather dense and localized in the shallow water where the first specimen was collected, whereas they appeared more scattered among the other *Utricularia* species (as indicated by flowering stems) where the second specimen was collected. A few other patches of

FIGURE 3. Unmounted specimen of *Utricularia ochroleuca* from the site on Keweenaw Peninsula, Michigan (*Graeff 0037*). An immature turion is forming at the tip of the plant (upper right). Photo by Garrett E. Crow.

U. ochroleuca were observed flowering around the edge of the flooding, indicating an overall scattered distribution at the site.

Utricularia ochroleuca has been proposed for formal endangered species protection under the Endangered Species Act of the State of Michigan (A. A. Reznicek, personal communication 13 Sept. 2019).

Diagnostic Characters. *Utricularia ochroleuca*, *U. intermedia*, and *U. minor* are similar vegetatively in that all three form dimorphic shoots (both green and white non-photosynthesizing branches, the green leafy branches having distinctly flat leaf segments). *Utricularia ochroleuca* is readily distinguished by a light yellow flower with a short spur about half as long as the lower lip (2.2–3.5(–5) mm long) and oriented at approximately a 45–90° angle from the lower lip, and bladders that are borne mostly on non-photosynthesizing branches and sparsely on green leafy branches. This contrasts with the somewhat brighter yellow flowers of *U. intermedia*, which have a spur that is narrower, constricted at the base, and nearly the full length of (4–7 mm long), and appressed to, the lower lip (Figure 1), and bladders that are restricted to the white non-photosynthesizing branches. *Utricularia minor* has dull yellow flowers with almost no spur (broadly conical, 1.5–3.2 mm long), and the lower lip is strongly curved downward, with the palate obscure, and bladders occur sparsely on the green leafy

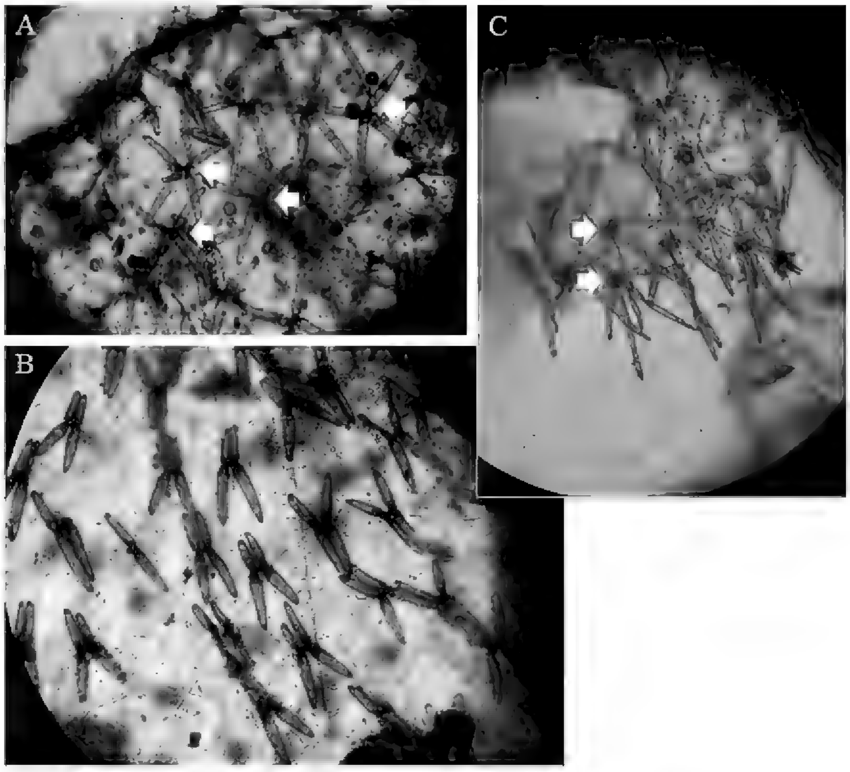

FIGURE 4. Quadrifids from representative species of *Utricularia*. (A) *Utricularia ochroleuca*. From specimen collected in the Thunder Bay District of Ontario, Canada. *Catling et al.* s.n. Aug. 14, 1984 (DAO). (B) *Utricularia intermedia*. From specimen collected in Papoose Lake, Kalkaska Co., Michigan. *Crow 10173* (MSC). (C) *Utricularia minor*. From specimen collected on Modland Island, Alpena Co., Michigan, *Voss 13988* (MSC). Quadrifid preparations (400×) by Garrett E. Crow.

branches as well as non-photosynthesizing branches. The margins of the distal-most flat leaf segments of *U. minor* are entire, while (0–)3–6(–9) setulose teeth on *U. ochroleuca*, and (5–)9–12(–20) teeth on *U. intermedia*. The turions of the three species are also diagnostic late in the season. *U. intermedia* has the most distinctive and largest turions: oblong, 7–11(–15) mm diameter, strongly setulose with white bristles on margins of scale-like leaves, giving a silvery appearance. Turions of *U. minor* are globose, non-setulose (few fine bristles at leaf tip), 3–4 mm diam., green). While turions of *U. ochroleuca* are globose, sparsely setulose (toward leaf tips), (1.5–)2–3(–3.5) mm diam., (appearing naked), green (see Figure 3), thus somewhat intermediate between the two species, but more like *U. minor* (Crow 2015b).

While *U. ochroleuca* can be readily distinguished from *U. intermedia* and *U. minor* when these are flowering, too frequently it only occurs in the vegetative stage, complicating identification. In wrestling with this problem for determining species of *Utricularia* in the Nordic countries, Thor (1988) discovered that the morphology of the quadrifids (glandular trichomes) that line the inside wall of each of the bladder traps could be used to distinguish the various species in their region. By taking measurements of the angle between the arms of the quadrifids as well as lengths of the arms he was able to incorporate information into a key to the six Nordic species—*U. vulgaris* L., *U. australis* R. Brown, *U. minor*, *U. intermedia*, *U. ochroleuca*, and the newly described *U. stygia* Thor (which is very similar to *U. ochroleuca*)—based only on quadrifids.

Drawing from Thor's study and citing the rarity of flowering in both *U. stygia* and *U. ochroleuca* as well as the unreliability of the number of teeth along the leaf segments as diagnostic, Plachno and Adamec (2007) embarked on a study of the differentiation of the two taxa based on the quadrifid glands for plants of the Czech Republic. They concluded that the only statistically reliable criterion distinguishing these two species in the sterile state is the measurement of the angle between the shorter arms. Crow (2015a) applied this information from Thor (1988) and from Plachno and Adamec (2007) to the problem of distinguishing *U. ochroleuca* by the morphology of the quadrifids, especially focusing on measurements of hundreds of quadrifids of *U. ochroleuca*, *U. intermedia*, *U. minor*, *U. vulgaris* subsp. *macrorhiza*, as well as to determine whether *U. stygia* occurs in North America. He found that the quadrifids (Figure 4) reliably distinguished *U. ochroleuca* (with mean angle 128.9°; range 111°–146°) from *U. intermedia* (with mean angle 28.6°; range 16°–42° or arms closed) and *U. minor* (arms usually reflexed), but not from depauperate, sterile specimens of *U. vulgaris* subsp. *macrorhiza* (Leconte ex Torrey) R. T. Clausen (with mean angle 133.9°; range 114°–154°). However, in considering specimens that might fit Thor's concept of *U. stygia*, it was not possible to consistently distinguish those from U. *ochroleuca*, and considering the overall variability seen in quadrifid morphology, it was more practical to treat the *U. ochroleuca* complex more broadly and not formally recognize *U. stygia* as distinct (Crow 2015b).

Specimen Citations. MICHIGAN: Keweenaw County, T58N, R32W, S ½, SW 1/4, Sec. 36; 47.37487°, –88.31012°. Edge of old beaver flooding on W. Branch Eagle River at Cliff Mine site. Among sticks on north shore of pond at muddy edge. Some entangled among roots of associates: *Eleocharis acicularis, Equisetum arvense, Juncus articulatus, Bidens cernua, Equisetum fluviatile, Leersia oryzoides, Impatiens capensis, Cerastium* sp., *Persicaria* sp., *Typha latifolia, Cicuta bulbifera, Agrostis* sp. *Alex Graeff 0036*, August 30, 2019 (MICH, MSC). 47.37397°, –88.31002°. Pond in sedge mat at edge of flooding, with *Utricularia intermedia* and *U. minor*. *Alex Graeff 0037*, August 30, 2019 (MICH, MSC).

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BOOK REVIEW

Daniel D. Palmer. 2018. *Michigan Ferns & Lycophytes: A Guide to Species of the Great Lakes Region.* University of Michigan Press, Ann Arbor. x + 381 pp., paperback $29.95. ISBN 978-0472-03711-7. ebook $23.95. ISBN 978-0-472-12365-0.

Botanists and plant enthusiasts in Michigan are fortunate in having several recent and up-to-date guides to the state's flora, including the comprehensive *Field Manual of Michigan Flora* (2012) by Edward G. Voss and Anton A. Reznicek, *Michigan Trees* (revised and updated edition, 2004) by Burton V. Barnes and Warren H. Wagner, Jr., and *Michigan Shrubs & Vines* (2016) by Burton V. Barnes, Christopher W. Dick, and Melanie E. Gunn. To these is now added this excellent and complete guide to the ferns and lycophytes of the state.

The main descriptive portion of the book is divided into four major groupings: Equisetaceae, Ferns (Polypodiopsida), Ophioglossaceae, and Lycophytes.[1] Each of these four parts contains a separate treatment for each species that includes the scientific name, important synonyms, one or more common names, a description of the species as it occurs in Michigan, a description of the habitat, and a discussion of the distribution in Michigan as well as, in general terms, its overall distribution. A dot map accompanies each species account with a dot in each county in the state in which the species is known to occur, based on herbarium specimens, as well as "knowledgeable persons, literature searches, fieldworkers, and [the author's] own experience." In addition, each species is illustrated, usually with scans of fresh material, if available, otherwise dried material. Details in the illustrations are also often marked with numbered arrows, keyed to data in the captions, and sometimes contain drawings of critical features. The descriptions are excellent, helpfully divided into paragraphs for each character, which is itself indicated in boldface type.

The book is amply provided with identification keys, but with some curious lacunae and inconsistencies, none of which are indicated in the discussion of how to use the keys in the Introduction. To allay the confusion that first-time users of the book may experience (as I did) in finding keys and descriptions, the following tips may be useful. The first section, Equisetaceae, contains a key to the species in the only genus, *Equisetum*. In addition, there is a very useful two-page chart comparing the species with respect to six major characters, and a description of the genus arranged in the same manner as the descriptions of individual species as described in the previous paragraph. The second section, devoted to "Ferns," has no description of that group at all, but does have a key to genera. The genera in this section

[1]Note, however, that the Introduction indicates that the descriptive portion divides the pteridophytes into two parts, the first containing the ferns, stated to include the Polypodiopsida (later diverging ferns), *Equisetum*, and the Ophioglossaceae, and the second containing the lycophytes. But this organizational scheme is not reflected either in the layout of the book or in the table of contents.

are arranged alphabetically without regard to family. For each genus with more than one species, there is a key to species. Descriptions of the families and keys to genera within families appear only in an appendix. However, there is no key to families, either in the main portion of the book or in the appendix. The third section, Ophioglossaceae, which has four genera, has no key to genera or description of the family at the outset of the section. There is, however, a table comparing the four genera with respect to each of 14 characters, and a key to species under each of the two genera with more than one species. At the beginning of the section, the reader is directed to the appendix for "a description of the family and a key to the Michigan genera." The fourth section, Lycophytes, includes three families. Two of the families have only one genus, but there are keys to the genera of Lycopodiaceae, and to the species in all genera with more than one species. A key to the families of lycophytes is provided in the appendix.

There is much more than this in this fine book. Throughout, one can find tables comparing various taxa with respect to several characters. There is much discussion of hybrids, although these are not given full treatment or included in keys; a particularly noteworthy example is the discussion under *Dryopteris*. Each species account provides an etymology of the scientific name and provides a discussion of the species, sometimes quite extensive, that often includes habitat information and additional distinguishing information, sometimes with respect to look-alike species in other genera that would not be included in the generic keys. There are, in addition, extensive discussion sections under many genera and families.

An introduction provides a substantial overview of fern and lycophyte biology, including such topics as life cycles, reproductive biology, evolutionary history, and ecology, as well as the history of the study of ferns in Michigan. The appendix includes an enumeration of the state, national, and global status of rare and endangered species of pteridophytes in the state. The book concludes with a short essay on the evolution of taxonomic concepts, a glossary, a bibliography, and an index.

A minor quibble: the subtitle of the book, "A Guide to the Species of the Great Lakes Region," is misleading, because it implies that all species of ferns and lycophytes that occur in the Great Lakes region (a term that is not defined in the book or otherwise even mentioned) are included, whether or not they occur in Michigan. That is not the case; only species known from Michigan are treated in this book, and users cannot therefore be confident that any pteridophyte encountered in the broader Great Lakes region will be treated. To give three examples: (1) *Isoëtes butleri* and *I. melanopoda* are both known from northeastern Illinois, within the Great Lakes region, but are absent from this book. (2) *Woodwardia areolata* is mentioned in passing (because it was reported from Van Buren County in 1880), but no means of identifying it is provided. However, it is currently known from the Indiana Dunes area in northwestern Indiana and from Cook County, Illinois, both at the southern end of Lake Michigan. (3) The book mentions that *Cystopteris montana* and *C. tennesseensis* are known from the northern shore of Lake Superior and should be sought in Michigan, although no means of identification are provided. *Cystopteris tennesseensis* is also known from northeastern Illinois and is fairly widespread in Wisconsin.

This outstanding guide should make life much easier for all of those seeking to learn more about this fascinating group of plants in Michigan.

—Michael Huft

ISOBEL DICKINSON MEMORIAL AWARD RECIPIENT

Congratulations to **Alan W. Stockdale**, who is the recipient of the Isobel Dickinson Memorial Award for **best student-authored paper** published in *The Great Lakes Botanist*, Volume 58, 2019. The selected paper is entitled "Floristic Quality Assessments of Remnant Natural Areas in the Greater Grand Rapids, Michigan Region: Evaluating Botanical Change Since the 1890s" by Alan W. Stockdale, Garrett E. Crow, and David P. Warners, The Great Lakes Botanist 58: 2–31. We acknowledge the Michigan Botanical Club—Dickinson Award Committee (Gary Hannan, Liana May, and Dan Skean) for evaluation of the nominated student papers and the Michigan Botanical Foundation for funding this award.

REVIEWERS FOR 2019 AND 2020

I wish to thank the following people who reviewed manuscripts during 2019 and 2020 for *The Great Lakes Botanist*. Their comments were important, both to the authors and to the editor, and their efforts, which are essential to maintaining the high quality of the journal, are greatly appreciated.

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INSTRUCTIONS TO AUTHORS

Refer to http://quod.lib.umich.edu/m/mbot/submit for more detailed instructions, especially for formatting, style conventions, literature cited, and voucher specimen requirements. Please contact the editor with any questions.

1. Create text in 12-point Times New Roman font and double space paragraphs throughout. Research articles should be organized as follows: Title, Author(s) and address(es), Abstract with up to 5 keywords, Introduction, Materials and Methods, Results, Discussion, Acknowledgements, Literature Cited, Tables, Figure Legends, and Figures. Sections may be omitted if not relevant. All pages should be numbered.

2. For noteworthy collections, manuscripts should be formatted as follows. The title, "Noteworthy Collections," should begin each submitted manuscript, followed on the next line by the State or Province for the species reported. The next line should list the taxon of interest using the following format: Species Author(s) (Family). Common name. The rest of the manuscript should include the following named sections: (i) Significance of the Report, (ii) Previous Knowledge, (iii) Discussion, (iv) Diagnostic Characters (if desired), (v) Specimen Citations, (vi) Acknowledgements (if desired), and (vii) Literature Cited. Each of these sections is largely self-explanatory; however, the "Significance of the Report" section should be limited to a brief sentence or phrase indicating the significance of the collection(s), and this may be expanded upon in the "Discussion" section; the "Specimen Citations" section should include the relevant label data from the voucher specimen(s) including location data, collector(s), collection number, etc., as well as the Index Herbariorum acronym(s) of the herbarium or herbaria where the specimen(s) are deposited. The manuscript should end with the name and address of the author(s).

3. Non-research articles, such as book reviews, letters to the editor, notices, biographies and other general interest articles can be formatted as general text without the specific sections listed above. However, literature cited and any tables or figures should be formatted as described below.

4. Create tables as a MS Word table. Each table is to be submitted as a separate file. Table captions should be placed at the top of the table. Any footnotes should appear at the bottom of the table. Please do not insert tables within the body of the text.

5. Send each figure as a separate file in a high-resolution format—eps, jpg, or tif. Figures like bar graphs that gain their meaning with color won't work—use coarse-grained cross-hatching, etc. Create figure legends as a separate text file, and the typesetter will insert them as appropriate. Please do not insert the figure in the body of the text file.

6. Citations: Please verify that all references cited in the text are present in the literature cited section and vice versa. Citations within the text should list the author's last name and publication year (e. g. Smith 1990). For works with more than 2 authors, use "et al.", and separate multiple citations with a semicolon.

7. Literature Cited: List citations alphabetically by author's last name. The first author's name is to be listed with surname first, followed by initials (e.g. Smith, E. B.), and subsequent authors are to be listed with initials first.Separate author's initials with a single space. The year of publication should appear in parentheses immediately before the title of the citation. The entire journal name or book title should be spelled out. Please put a space after the colon when citing volume number and page numbers.

8. Italicize all scientific names. Voucher specimens must be cited in floristic works and in any other study whose results depend on the identity of the plant(s). Papers citing plant records without documenting vouchers are generally not acceptable.

9. Manuscripts must be submitted electronically to the email address of the editor. All manuscripts will be reviewed by at least two referees.

CONTENTS

On the cover: *Saxifraga paniculata*, on the rocky shoreline of Lake Superior. In the Great Lakes, this species is limited to Isle Royale, Michipicoten Island, and eight sites on the north shore of Lake Superior. Photo by Sarah Johnson.

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